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CONTENTS

Original Papers:

Preliminary Report on the Residual Kaolin and Feldspar in the Pacific Northwest—Wilson, Bennett, and Heath 475
An Automatic Direct Reading Laboratory Scale for Weighing Briquettes—Schurecht 491
Composition and Properties of Diaspore, Bauxite and Gibbsite—Howe and Ferguson 496
Diaspore Clay of Arkansas and Missouri—Wysor 501
The Effect of Heat-Treatment and Composition of Semi-Porcelain Bodies on Crazing—Sproat 510
Deformation Studies of Silicates and Aluminum Silicates of the Alkalies—Rice 525
The Continuous System of Grinding Ceramic Materials—Hardinge 548
The Value of Screen Analysis in Ceramics—Nickerson 563

Ceramic Abstracts 43

The Bulletin:

Editorials 15
Discussion on "Refractories for Oil-Burning Furnaces" 19
Discussion on "Calcining of Clays" 20
Discussion on "Mechanical Methods from Clay Bank to Machine" 25
Discussion on "Tentative Specifications for Glass House Refractories" (with Report of Committee on Glass Industries Refractories) 29
Discussion on "Elimination of Streaks in White Opaque Glass" 38
Activities of The Society 39
Notes and News 45

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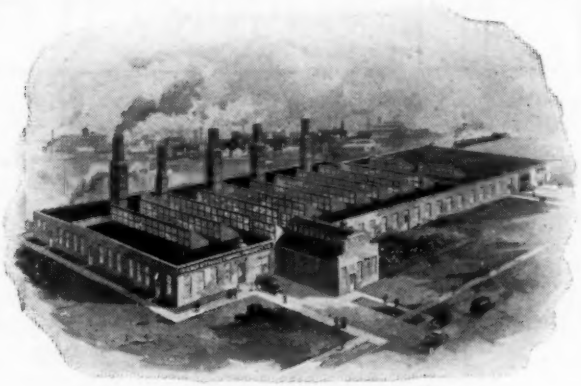

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ORIGINAL PAPERS

PRELIMINARY REPORT[1] ON THE RESIDUAL KAOLIN AND FELDSPAR IN THE PACIFIC NORTHWEST

By Hewitt Wilson, A. Lee Bennett and Fred T. Heath

ABSTRACT

Large quantities of residual crystalline kaolin are found in the Inland Empire district of eastern Washington and northwestern Idaho. Preliminary investigation has shown that the properties of these clays, when properly selected and purified, will compare favorably with those of the English china clay upon which the eastern potters and paper manufacturers are largely dependent. With the low cost of the English clay laid down on the Atlantic Coast, it is not believed that the Pacific Northwest clay will be used as a substitute for the English in the eastern markets, but the domestic source will provide the bulk of the raw material for the future whiteware industry in the Pacific Northwest. Commercial quantities of feldspar, quartz, and fire clay are also found in the Pacific Northwest.

The work described here was conducted at Seattle under a coöperative arrangement between the College of Mines, University of Washington, and the Northwest Experiment Station of the U. S. Bureau of Mines.

The Importance of Residual Kaolins in the Manufacture of Porcelain and Whiteware Bodies

Messrs. Schurecht,[2] and Jones[3] have noted the importance of devel-

[1] Published by permission of the Director of the U. S. Bureau of Mines, 1922.

[2] H. G. Schurecht, "The Microscopic Examination of the Mineral Constituents of Some American Clays," *Jour. Amer. Ceram. Soc.*, **5**, 3–24 (1922).

[3] C. H. Jones, "Pottery Manufacture in the East Liverpool District," *Chem. and Met. Eng.*, **26**, 350 (1922).

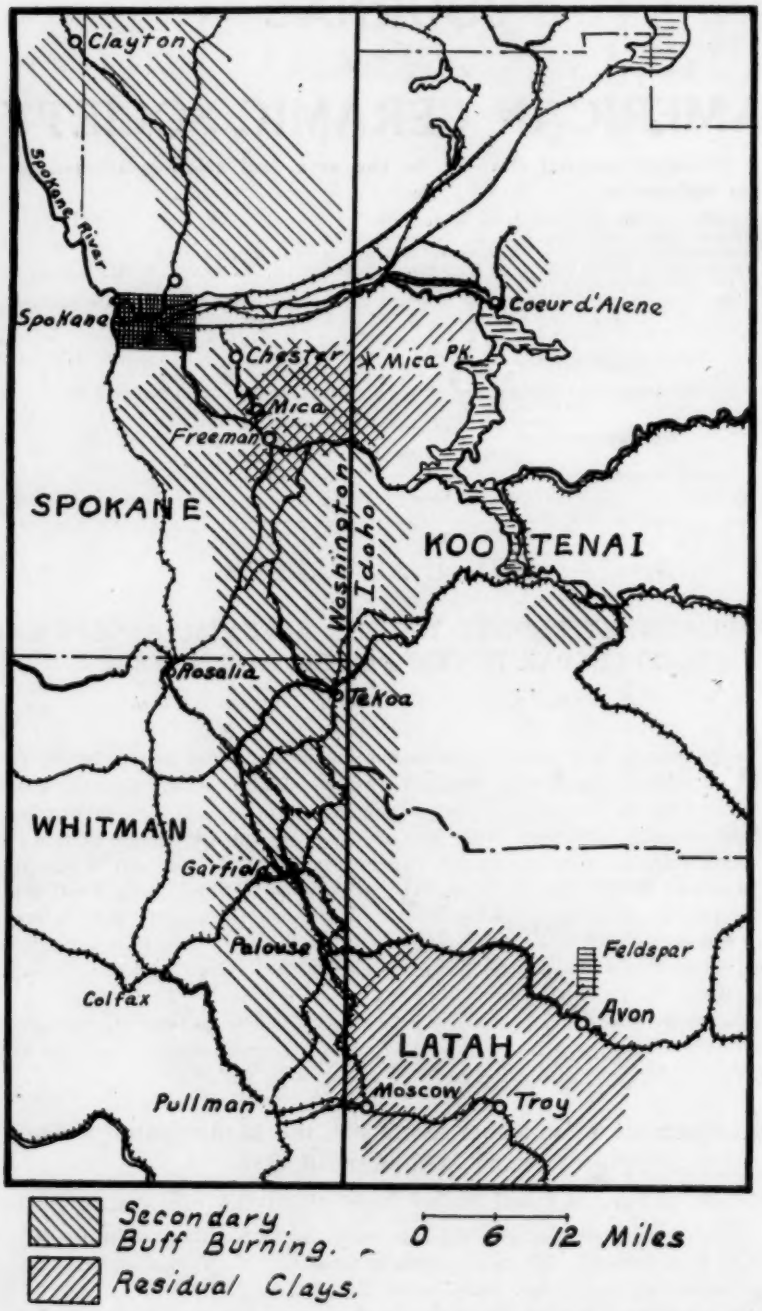

FIG. 1.—Map of the Inland Empire of eastern Washington and northwestern Idaho.

oping in the United States new deposits of the crystalline type of kaolin for the whiteware industry. English china clay from Cornwall has the widest use and best reputation among the potters of the East and hence is held as a standard for all American china clays. Two general classes of kaolins are found in the eastern part of the United States. The first, represented by small deposits in North Carolina, has a geological history similar to that of the English, and is composed in large part of the platy crystalline kaolinite,[1] but the particles are coarser, the plasticity weaker, and the available quantity limited. Small deposits of residual kaolins are likewise found in Pennsylvania and Delaware.

The transported white clays of Georgia, South Carolina, Florida, and Pennsylvania consist largely of "colloidal" kaolin particles and are thus finer grained, more plastic, and stronger, but have a greater shrinkage and entirely different working properties from the English china clay. Experiments conducted under the stress of the war shortage showed that mixtures of the two types of American clays will give bodies which duplicate the English china clay very closely, but the unfortunate part of the situation is that while the "colloidal" kaolins can be found in great abundance, the residual kaolins of North Carolina, Pennsylvania, and Delaware are limited in amount. Thus very little hope is offered toward the complete independence of the American potter and paper manufacturer from the English or some other foreign china clay.

Shortage in the eastern part of the country, combined with the need of a whiteware industry in the Pacific Northwest, has led to the investigation of the deposits of residual kaolin in the celebrated Inland Empire region of eastern Washington and northwestern Idaho. These clays have already been used for a number of years by four companies for making a "white" grade of fire brick.

General Geology of Central Eastern Washington and Northwestern Idaho[2]

The rocks of Spokane, southeastern Stevens, and Whitman Counties in Washington, and Latah County, Idaho, consist principally of granite, quartzite, and basalt. The quartzite, which is the oldest and is probably pre-Cambrian, has altered in places to quartz schist and gneiss. The granite occurs as a large intrusion into the quartzite and quartz schists

[1] G. Hickling, "China Clay, Its Nature and Origin," *Trans. Inst. Min. Eng.*, **36**, 1908–1909. R. E. Somers, "Microscopic Examination of Clays," *Jour. Wash. Acad. Sci.*, **9**, 113 (1919). H. G. Schurecht, *loc. cit.*

[2] E. K. Soper, "Fire Clays of Northern Idaho," *Jour. Amer. Ceram. Soc.*, **1**, 94 (1918). Sheldon L. Glover, *Wash. Geol. Surv.* Unpublished notes. Frank H. Skeels and Hewitt Wilson, "A Preliminary Report on the Clays of Idaho," Bureau of Mines and Geology, State of Idaho, *Bull.* **2**, 1920.

and is probably of Cretaceous Age. This enormous granite batholith is now exposed over many square miles in the Rocky Mountain region to the east and southeast in Idaho. In the white clay district of lower elevation the quartzite and associated pre-Cambrian sediments have mostly been eroded or buried.

The basalt is of Miocene Age and occurs as a series of flows which originally covered a large area in southeastern Washington (approximately bounded by the Columbia and Spokane Rivers on the west and north, respectively), the Snake River plains in Idaho, and a large part of eastern Oregon. Erosion has removed or softened a large part of the thinner capping which occurs at the higher elevations (2,200 to 2,500 ft.) and has exposed the weathered granite masses beneath. Wood fragments occurring between the residual clays and the overlying basaltic material indicate an old weathered surface which antedates the volcanic activity. In many places the basalt capping has prevented the erosion of the soft clays beneath, hence the age of the residual clay may vary from pre-Miocene through Miocene to post-Miocene. The softening of the basalt capping to form red and brown-burning clays is often accompanied by the staining of the underlying white clays by percolating waters, and where the two have been removed and deposited in other places together, dark-burning, semi-refractory clays will be found.

The granite from which the residual white clays were formed is rich in feldspar and low in hornblende, biotite, and the other ferro-magnesian minerals. In a small belt, about two miles wide and several miles long, located from three to six miles north of Avon, Idaho, well-developed pegmatite is found, in which it is possible to mine white mica, feldspar, and quartz, in commercial quantities.[1] Mica mines have been operated there intermittently since 1888, and the feldspar and quartz discarded on the spoil dumps.

Because of the great age of these granites and their long exposure to weathering agencies with unfavorable conditions for the removal of the softened products, it is believed that the residual beds will produce an enormous tonnage of white-burning clay. The deposits which have been opened at the present time for fire clay give indications of very large underlying quantities.

Description of Residual Clay Openings

Freeman, Washington, Pit (Fig. 2).—The residual clay is taken from a pit just north of the Freeman Station on the Spokane and Inland Empire Railway, shipped to Clayton, mixed with a more plastic clay, and made into fire brick. The pit measures about 150 feet in diameter and extends

[1] D. B. Sterrett, "Mica in Latah County, Idaho." U. S. Geol. Surv., *Bull.* 530, "Contributions to Economic Geology," [1], 377–83, 1911.

FIG. 2.—Residual kaolin pit at Freeman, Washington, property of the Washington Brick, Lime and Sewer Pipe Co.

back into one of the hills forming the shoulders of Mica Peak. The overburden varies from 2 to 10 feet and the working face, more than 30 feet high, shows no indications of the hard, unweathered granite floor. Large masses of the kaolin, quartz, and mica mixture still retain the original graphic granite structure.

Joel, Idaho, Fire Clay Pit[1] (Fig. 3).—This pit is three to four miles southeast of Moscow and is reached by a side road from the main highway leading to Troy. It lies at an elevation of 50 to 60 feet above the highway in a hillside and has a 30-foot vertical working face, with only two feet of overburden, the remainder being a mixture of quartz, clay and mica. Partial sorting of the clay from quartz by movements

FIG. 3.—Residual kaolin pit at Joel, Idaho. The clay is used for fire brick by the Moscow Fire Brick Co.

[1] Private communication from E. F. Goodner, Washington Brick, Lime and Sewer Pipe Co., Spokane, Wash., and Dean F. A. Thomson, State Bureau of Mines and Geology, University of Idaho, Moscow, Idaho.

that have taken place within the deposit permit the easy elimination of masses of very sandy material. The mined product is a high-grade plastic material used at Moscow by the Moscow Fire Brick Company on the auger machine without other clays. An immense deposit is indicated by this exposure.

FIG. 4.—The Johansen fire clay pit. This residual kaolin is used for fire brick by the Idaho Fire Brick Company at Troy, Idaho.

FIG. 5.—The Lindeman fire clay pit. This residual kaolin is used by the Idaho Fire Brick Company for fire brick at Troy, Idaho.

Johansen Pit[1] (Fig. 4.)—The pit is located about five miles northeast of Troy, Idaho, one-fourth mile from the highway to Deary. A 15-foot

[1] Private communication.

exposure of very clean kaolin with only a small percentage of coarse quartz is found here. The clay is hauled by truck to Troy for fire brick manufacture at the Idaho Fire Brick Company's plant.

Lindeman Pit[1] (Fig. 5.)—Another excellent deposit of similar material is found one mile uphill from the Johansen pit. It likewise is hauled by truck to Troy for making fire brick.

Exposure One Mile North of Mica, Washington (Fig. 6.)—Similar white and gray material is exposed in a railroad cut about one mile north of Mica, Washington. A 40-foot face, deeply cut by erosion, lies within a few feet of the railway track and undoubtedly will prove valuable.

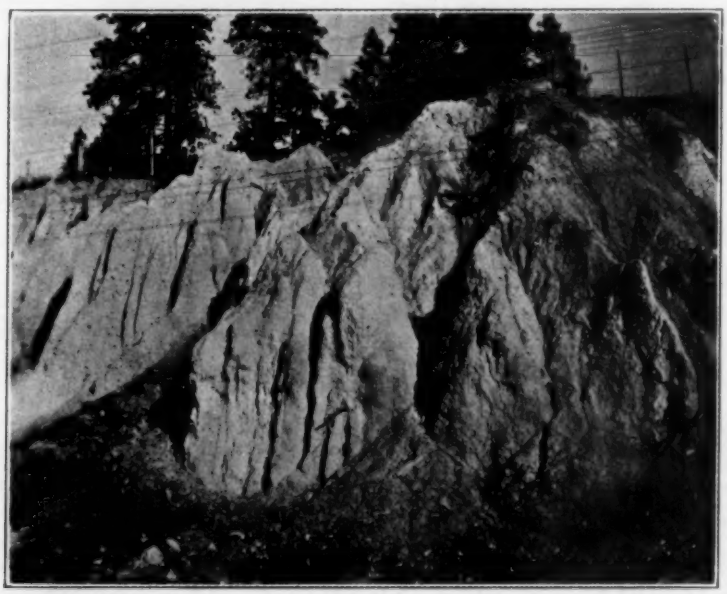

FIG. 6.—Unused deposit of residual kaolin in railroad cut one mile north of Mica, Washington.

American Fire Brick Company's Fire Clay Pit (Fig. 7.)—The north or fire clay pit shows light-burning clay which has been concentrated either by colluvial action or by settling and movements within the bed. The pit measures about 300 feet in length and has a working face at the end, 75 feet wide and about 12 feet high. A much greater amount would be available if the workings were carried to more depth, for as far as known the granite basement has never been touched in this vicinity. The deposit is stripped and the plastic clay blasted out of the bed and hauled directly to the plant for a white-burning grade of fire brick.

[1] *Loc. cit.*

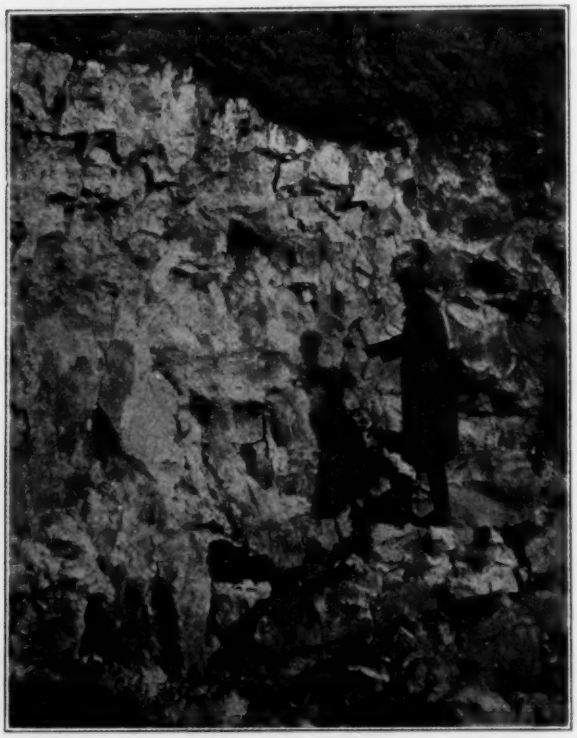

FIG. 7.—American Fire Brick Company's North or Fire Clay pit face of white-burning clay.

Feldspar and Mica Deposits

D. B. Sterrett[1] gives the following description:

The deposits lie in a north-south belt about two miles wide and several miles long. The mines and prospects examined are in T. 41 N., R. 2 W., from three to six miles north of Avon. They lie at elevations of 3,400 to 4,700 feet above sea level, along the top and to the west of a high mountain ridge extending south from the Thatuna Hills.

The mica deposits occur in an area of highly schistose metamorphic rocks of pre-Cambrian Age. Muscovite and biotite schists and gneiss in which quartz is generally a prominent constituent, are the principal rock types of the region. Locally certain bands of the gneiss have an abundant development of black tourmaline crystals, especially near large pegmatite bodies. The gneisses and schists of this region strike roughly north and south, and the dips range from 50° W. to vertical. Masses of pegmatite cut the gneiss and schist and are in many places entirely conformable with the schistosity and in others only in part or not at all. Some of the pegmatite bodies outcrop continuously for distances of several hundred yards, with few variations in thickness or direction. Others have smaller outcrops. A bulging or swelling of the peg-

[1] D. B. Sterrett, *loc. cit.*

matite bodies into chimney-like deposits also occurs and gneisses and schists apparently contain more pegmatite in the valley to the west of the high mountain ridge than in the ridge itself.

The principal properties are the Muscovite claim of Alexander Munro about five miles north of Avon, in sec. 22; the Levi Anderson mine, about four miles north of Avon, in secs. 22 and 27; the Maybe mine of Alexander Munro about one mile southwest of the Muscovite claim in sec. 22; the Luella mine of the Western Mica Company about 1½ miles southwest of the Muscovite in sec. 21; and the Last Chance mine of Mrs. May Jorgensen of Seattle.

Commercial bodies of feldspar were found in the Last Chance, Luella, and Muscovite mines.[1] At the Last Chance mine there are several large dumps of clean feldspar and some which contain about 50 per cent quartz. As far as can be judged, there is a large quantity of feldspar available. Transportation can be managed by means of a logging road which is under construction to within a mile of the mine. The Luella mine has two adits which cut large bands of clean feldspar in several places. The Muscovite mine shows the most extensive workings and the dumps indicate that large bodies of feldspar and mica have been opened. A bank of semi-kaolinized feldspar is exposed for at least 20 feet. Feldspar dikes 16 feet in width were found in tunnels No. 2 and No. 3 and could be removed with very little quartz and tourmaline. Complete descriptions of these mines in regard to the mica can be found in *Bull.* **530,** U. S. Geological Survey.

Secondary Buff-burning Clays

The basalt flows blocked the natural drainage of the country and developed many lakes and ponds at the foot of the hills near the boundaries of the flows. In some of these were deposited the white kaolin-like clay material, although it often is contaminated with surface wash containing iron impurities. Thus numerous deposits of fine-grained soft, plastic clays were formed in well-stratified beds. Leaf fossils are often found on bedding planes, and limonite or bog iron ore in nodules or sheets is associated with practically all these light-colored clays.

We have here, then, on a smaller scale, a reproduction of the clay-forming conditions of the Appalachian highlands and surrounding territory. From the softened granitic deposits of which only a few remnants remain, such as the North Carolina and Pennsylvania residual kaolins, the kaolinitic materials were removed and carried to the east and south-east into New Jersey, South Carolina, and Florida, to form the secondary fire clays and kaolins, and to the west into Kentucky and Tennessee to form the fine-grained and plastic ball clays.[2] The latter, having journeyed

[1] Private communication, *loc. cit.*

[2] R. A. Schroeder, "Ball Clays of West Tennessee," *The Resources of Tenn.*, **9,** 93 (1919).

farther and having been mixed with more impurities and subjected to greater organic action, have a greater colloidal development and a fired color further removed from pure white.

In northwestern Idaho and eastern Washington, we have an even greater distribution of the residual masses of softened granite rock which have not been deeply cut by erosion, while the seondary, the finer grained, the more contaminated, and more plastic clays, lie to the west at lower elevations. The basalt blockade produced a series of swamps and lakes of quiet water comparable to the northern part of the Embayment area in Tennessee, Kentucky, and Illinois near the close of the submersion period.

FIG. 8.—Conner secondary clay pit, east of Clayton, Wash. Clay is used for terra cotta and stoneware.

Conner Plastic Clay Pit. (Fig. 8.)—The S. M. Conner clay pit is in the NE. ¼, NE. ¼ sec. 4, T. 29 N., R. 42 E., about five miles from Clayton. The pit lies in an old flat lake country surrounding Clayton and Deer Park and but a short distance from the old granitic hills. It measures about 75 feet by 125 feet and has been excavated to a depth of about 12 feet. An overburden consisting of loam, water worn pebbles, and coarse yellow sand varies from 3 to 7 feet in thickness. Separating this probable glacial drift from the clay is a continuous layer of limonite averaging about four inches in thickness. The clay occurs as thick-bedded, horizontal

strata, light gray to nearly white in color, and extends to a depth of over 30 feet. At the present time the clay is used for the manufacture of terra cotta at Clayton and stoneware at Spokane.

Some of the other deposits of a secondary type are found at:

1. Clayton, Wash. Property of the Washington Brick, Lime and Sewer Pipe Company. Used for fire brick and face brick.

2. Abbott Pit. NW. ¼, sec. 32, T. 30 N., R. 42 E., about six miles north of Clayton, Wash. Used for terra cotta.

3. D. C. Neafus Pit. Three-quarter miles east of the Conner pit in the SE. ¼, sec. 34, T. 30 N., R. 42 E.

4. Chester Pits. SE. ¼, sec. 35, T. 25 N., R. 44 E., about three miles from Chester, Wash. station on the O. W. RR. and N. Co. Used for making terra cotta in western Washington.

5. Palouse, Wash. Old stoneware pottery about 1.5 miles south of Palouse. Many other pits and prospect holes are opened in Stevens, Spokane, and Whitman Counties.

Experimental Work on Whiteware Bodies

Samples of the commercially-mined fire clays were obtained through the courtesy of the Washington Brick, Lime and Sewer Pipe Company, the Moscow Fire Brick Company, and the Idaho Fire Brick Company, from the Freeman, Joel, and Johansen pits, respectively. These are designated in the following report as the Freeman, Moscow, and Troy clays, respectively.

Purification of the Kaolins.—In order to remove the coarse quartz, mica, feldspar, etc., the kaolins were blunged with water, screened through a 200-mesh sieve, filter-pressed, and dried. This crude washing process did not remove the fine quartz and mica. Therefore, a further separation of the Troy clay was made by settling and decantation. The Moscow and Troy samples approached a pure white color when dry, but the Freeman gave a light-cream tone.

As a basis of comparison, a sample of the Roessler and Hasslacher imported English china clay (washed) was tested with these clays. The former has an international use for whiteware and glaze work.

Testing, Methods and Results.—Standard-size test pieces (AMERICAN CERAMIC SOCIETY) were made separately from each of the three washed kaolins and from English china clay. Whiteware body mixtures were prepared for each clay separately by blunging together 50% of the clay, 30% of eastern Canadian feldspar, and 20% of flint. The plastic and dry results of these tests are given in the tables on following page.

TABLE I

	Sample		Per cent water of plasticity	Per cent pore water	Per cent shrinkage water	Per cent linear shrinkage
			On basis of dry weight			On basis of plastic length
100% clay	A–A	Freeman kaolin	54.1	23.2	30.9	9.4
100% clay	B–B	Troy kaolin	40.5	20.6	19.9	7.6
100% clay	C–C	Moscow kaolin	35.7	19.4	16.3	5.9
100% clay	D–D	English china clay	41.2	27.6	13.6	5.5
Whiteware body	A	Freeman kaolin	33.1	19.1	14.1	6.4
Whiteware body	B	Troy kaolin	29.9	16.9	13.0	5.7
Whiteware body	C	Moscow kaolin	29.6	18.5	11.1	5.2
Whiteware body	D	English china clay	29.5	21.5	8.0	4.3

TABLE II

DRY TRANSVERSE STRENGTH

Sample	100 Per cent clay	Whiteware body
Freeman kaolin	477.1 lbs. per sq. in.	332.2 lbs. per sq. in.
Troy kaolin	451.8 lbs. per sq. in.	336.4 lbs. per sq. in.
Moscow kaolin	442.9 lbs. per sq. in.	252.5 lbs. per sq. in.
English china clay	112.8 lbs. per sq. in.	98.5 lbs. per sq. in.

For the sake of comparison we list the transverse strengths of several kaolins, tested by Bleininger and Howat.[1]

TABLE III

Sample	100 Per cent clay	Clay with 50 per cent sand
Georgia kaolin (*a*)	325/sq. in.	210/sq. in.
Georgia kaolin (*b*)	269/sq. in.	182/sq. in.
Florida kaolin	239/sq. in.	122/sq. in.
North Carolina kaolin	166/sq. in.	82/sq. in.
Eng. china clay (M. G. R.)	98/sq. in.	52/sq. in.
Eng. china clay (M. W. M.)	74/sq. in.	56/sq. in.

These results would indicate that the Pacific Northwest kaolins possess greater dry strength than the others. Riddle and McDanel[2] in a series of tests on a number of porcelain bodies, obtained moduli of rupture varying from 140 to 250 pounds per square inch for unaged bodies of similar composition to those described here. Commercial china bodies tested by them were found to have moduli of rupture varying from 170 to 220 pounds per square inch. All of these values are lower than the results obtained on the porcelain bodies containing Northwest kaolins.

It is evident that the Freeman clay is more plastic than the others. The English china clay has a higher porosity in the dry state and this lack

[1] A. V. Bleininger and W. L. Howat, "The Compression, Tensile and Transverse Strength of Some Clays in the Dried State," *Trans. Amer. Ceram. Soc.*, **16**, 278 (1914).

[2] F. H. Riddle and W. W. McDanel, "Some Types of Porcelain," *Jour. Amer. Ceram. Soc.*, **1**, 606–27 (1918).

of compactness is also evident by the weaker dry strength. In regard to linear shrinkage, the Moscow kaolin compares most favorably with the English china clay sample. On the basis of the plastic length, the former possesses less than one per cent greater shrinkage in both the 100% clay body and the whiteware mixture.

Fired Properties.—The test pieces were heated in saggers in a gas-fired laboratory kiln to a series of temperatures corresponding to cones 5 to 14, and cooled with the kiln.

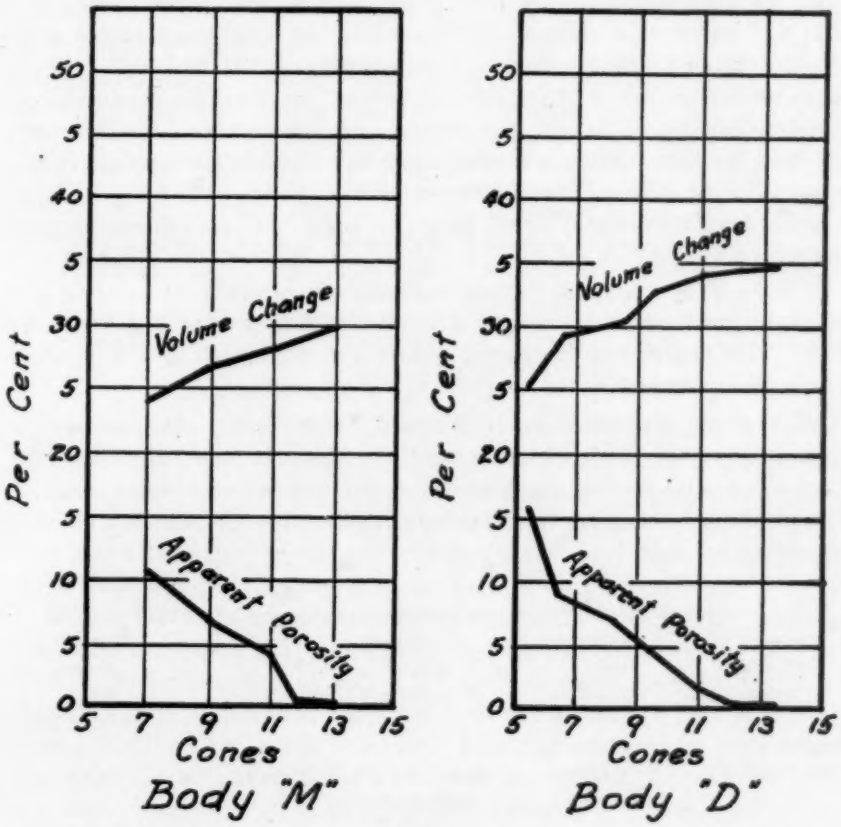

FIG. 9.

Body "A," containing Freeman clay, attained an apparent porosity of 2.0% and a volume change of 32.0% at about cone 13–14, which indicates that the density of commercial porcelains had not been obtained. Bodies "B" and "C," consisting of Troy and Moscow clays, respectively, possessed nearly identical properties, but likewise indicated that commercial porcelain density had not developed at cone 13–14. The volume change for both was 28% and the apparent porosity less than 1.0%.

Body "D" contained English china clay; the curves of its volume change and apparent porosity are shown in Fig. 9. This body is non-absorbent at cone 13.

The above-mentioned clay bodies from the Pacific Northwest possess strength, color, and density equal to many of the commercial whiteware bodies used for the cheaper but porous grades of ware. However, non-absorbent bodies were produced without raising the firing temperature by two methods, as follows:

1. An examination of the clays used in the above bodies "A," "B," and "C," shows that considerable free silica and mica remain even after washing through a 200-mesh sieve. An addition of 20% flint consequently raises the refractoriness of the mixture beyond the usual range of common porcelain bodies. This fact was proved by firing another series of bodies in which the flint content was eliminated and the feldspar content varied from 20% to 40%. The properties of the body with 30% feldspar compared very favorably with those of body "D" containing English china clay and flint.

2. The Troy clay was further washed very carefully by settling and siphoning methods to duplicate the purification of the English china clay. This eliminated the excess quartz and mica and gave a product which closely resembles the English clay in appearance.

Microscopic Examination of Washed Troy Kaolin.—A microscopic examination[1] was made of the washed Troy kaolin, and, as a basis for comparison, the washed English china clay sample also was examined. The results indicate that the Northwest kaolin also contains considerable crystalline kaolinite:

ESTIMATED PROPORTION OF MINERALS (Non-colloidal portion)

Sample	Very abundant	Considerable	Small amount	Trace
Troy kaolin (washed)	platy crystalline kaolinite[2]	micas ("sericitic")		zircon silica (as diatoms)
English china clay (washed)	platy crystalline kaolinite	micas (muscovite and sericite)	tourmaline	quartz (?)

Its mean refractive index was determined by oil immersion. A mixture of pure clove oil and α-bromonaphthalene was carefully prepared, which was just equal in refraction to the kaolinite plates. The refractive index of the mixture of oils was determined immediately, using an Abbé refractometer, the accuracy of which was previously checked by using known

[1] This work was done under the direction of Mr. Geo. E. Goodspeed, Professor of Geology, University of Washington, and Consulting Mineralogist, U. S. Bureau of Mines.

[2] The material recognized as "platy" kaolinite had low double refraction.

oils. The results thus obtained gave $n' = 1.553$ at 22°C. A comparison of the crystals with a pure sample of mono-brombenzene showed the kaolinite to be distinctly lower in refractive index than the mono-brombenzene, which was determined as $n' = 1.560$ at 25°C.

The refractive index of the crystalline kaolinite in the English china clay sample was also apparently lower than that of the mono-brombenzene (1.560), and the kaolinite in both Troy and English china clay samples was distinctly above 1.54 (Canada balsam).

Various authorities on this subject give different results for the refractive index of kaolinite:

	Name of author	Date	Refractive index	Publication
1.	H. G. Schurecht	1922	1.56–1.57	*Jour. Amer. Ceram. Soc.*, **5**, 3 (1922).
2.	W. E. Ford	1922	B = 1.482	Dana's "Textbook of Mineralogy," p. 578.
3.	E. S. Larsen	1921	B = 1.565	"Microscopic Determination of Nonopaque Minerals," U. S. Geol. Surv., *Bull.* **679**, p. 249.
4.	L. M. Luquer	1913	$n' = 1.55$	"Minerals in Rock Sections," p. 115.
5.	A. Johansen	1908	B = 1.54 (approx.)	"Rock-forming Minerals in Thin Section," p. 383.
6.	N. H. & A. N.	1909	$n' = 1.563$	"Elements of Optical Mineralogy," p. 269.
7.	J. P. Iddings	1906	$n' = 1.54$ (about)	"Rock Minerals," p. 454.

In the microscope slides, the Troy kaolin was very similar in appearance to the English china clay sample. A little iron-stained mica was found in both samples, the English china clay containing the larger amount.

The kaolinite crystals were apparently abundant in both samples, and about the same in size. Measurements showed the largest plates in both to be of approximately the same area as a 0.01 mm. square.

Whiteware Body Tests of Washed Troy Kaolin.—Body "M" contained 50% of this rewashed Troy clay, 30% eastern Canadian feldspar, and 20% flint. The firing curves of body "M" are also shown in Fig. 9 and a comparison can be made with body "D." A non-absorbent structure is produced at about the same cone with both bodies, but the fired volume change of the Troy clay body is less than that of the English. However, the dried volume change of the English body was less than that of the Troy, so that the total shrinkages are about equal. No cobalt was used in either body and the fired colors are very similar.

Idaho Feldspar.—A sample of feldspar from the Last Chance mine was obtained through the kindness of Dean F. A. Thomson of the University of Idaho. A chemical analysis gave the following:[1]

SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	CaO	Total
66.80%	19.65%	0.85%	7.20%	3.00%	2.01%	99.51%

[1] Analytical Department of the Northwest Experiment Station, U. S. Bureau of Mines.

This result indicates that the feldspar is one of the high soda-lime types. The cone fusion is 6–7 with fast heating.

Microscopic Examination.—Crushed fragments of the feldspar showed an index of refraction almost equal to that of Canada balsam (1.540). It hence is classified as an "intermediate" feldspar, probably largely composed of oligoclase. Some orthoclase also was present but in small quantity. Throughout the sample shreds of micaceous material, probably sericite, were found. Some tourmaline (colorless variety) was present as inclusions in the feldspar, which likewise showed cloudiness from alteration to kaolin.

No appreciable difference was noted when this material was substituted for the eastern Canadian feldspar. More extensive testing will probably reveal the properties peculiar to this feldspar

Summary

1. Simple washing tests were made of three Pacific Northwest kaolins and a more refined elutriation was made of a fourth.

2. Fired whiteware and porcelain bodies of these clays show results comparable with bodies containing imported English china clay.

3. Although these clays are classed as residual and contain an abundance of crystalline kaolinite, their weathering has been complete enough to produce such a high degree of plasticity and bonding strength that it may not be necessary to use the usual off-colored ball clay content for the necessary plastic and dry strength. However, the substitution of an open-burning clay for a dense-burning clay ordinarily should be accompanied by an increase in the flux content or the firing temperature to produce the same degree of vitrification.

4. These preliminary results will be followed by more complete testing to secure data for a future whiteware industry in the Pacific Northwest.

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AN AUTOMATIC DIRECT READING LABORATORY SCALE FOR WEIGHING BRIQUETTES[1]

By H. G. Schurecht

ABSTRACT

An automatic direct-reading laboratory scale has been designed in the Ceramic Laboratory of the Bureau of Mines, with which it is possible to weigh briquettes in about one-third the time required with balances. It is capable of weighing up to 150 grams in 50-gram intervals with an average accuracy of 0.05 gram. Although this particular scale was made for the above limits in accuracy and capacity, similar scales may be made in which this range may be modified as desired.

Introduction

Automatic direct reading scales have proved to be big time savers and indispensable to the industries, but heretofore no laboratory scales of sufficient accuracy have been made which register automatically for intervals greater than 2 grams. In the utilization of clays for ceramic purposes considerable time can be saved in testing by using automatic direct reading apparatus. It was the realization of the importance of such a scale for weighing clay briquettes, that prompted the writer to design one capable of weighing up to 150 grams in 50-gram intervals, with an average accuracy of 0.05 gram.

Construction

The scale herein described operates with levers similar to certain types of postal scales. Postal scales, however, have only one lever arm corresponding to the indicator lever used in the new instrument (Fig. 1). When a unit weight is placed on the pan of a scale of this type the indicator moves until the resultant force to the right balances that to the left of the main knife edge.

In a scale containing one lever the movements of the indicator for unit weights are of unequal magnitude in different portions of the stroke. As the pointer swings upward from the vertical or zero position, the movement of the moment arm to the left of the knife edge and of that to the right of the knife edge increases for the first 45° of the stroke. During the second 45° of the stroke the moment arm to the left of the knife edge decreases while that to the right increases. It is obvious therefore that the resultant force and hence the movement of the indicator per unit weight becomes less during the upper portion of the stroke.

Experiments conducted with a one lever scale of this type showed that if desirable spacing for the divisions is obtained in the lower portion of the stroke, the spacing would be too close through the upper portion. If

[1] Abstract of paper presented at the meeting of the American Ceramic Society, February, 1922, St. Louis, Missouri. Published by permission of the Director, U. S. Bureau of Mines.

adjusted so that the spacing for the unit divisions in the upper portion of the scale was large enough for practical purposes, the spacing in the lower portion would be so large as to limit the capacity of the scale. For a

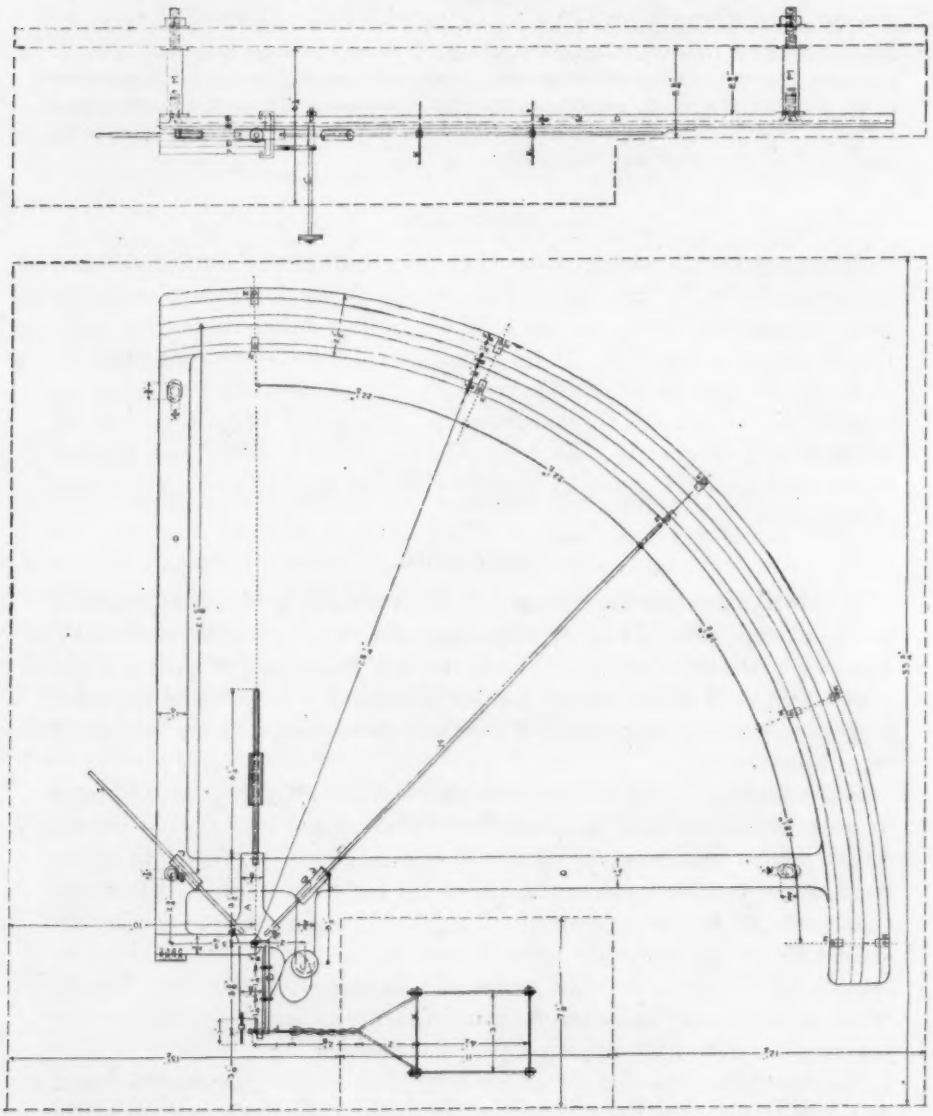

FIG. 1.

scale having maximum capacity and accuracy at the same time, it is desirable to have the divisions for unit weights approximately equal through the entire stroke of the indicator.

This was accomplished by placing a second lever above and at right angles to the indicator lever (Fig. 1). When the indicator lever is vertical or at zero, the center of gravity of the second lever has a maximum moment arm and reduces to the greatest extent the resultant force and hence divisions for a unit weight. As the pointer swings upward to the right 90°, the moment arm for this lever gradually decreases to zero. Hence by adjusting the weight on the indicator lever so the spaces of the unit division on the upper portion of the stroke are sufficiently large, those divisions in the lower portion may be made approximately the same by adjusting the center of gravity by means of the weight on the second lever at the proper distance from the knife edge. This condition is obtained when the equilibrium shown in equations 1, 2 and 3 below (p. 494) exist. In other words, the center of gravity is changed to meet the condition herein expressed.

The main arms and levers of the scale are made of an alloy composed of 10% copper and 90% aluminum. This alloy has the advantage over brass or aluminum in that it is very light, hence making the instrument more sensitive than if it were made with the heavier brass, and it is more rigid than aluminum, which although light is too flexible to be used for this purpose.

Since the main levers are all made of the same material, any expansion or contraction due to temperature changes would not affect the readings of this scale. All bearings and knife edges are made of agate to reduce friction.

The entire scale is enclosed in a case to prevent air currents coming in contact with the recording apparatus (Figs. 3 and 4).

Operation and Manipulation

When a 100-gram weight is placed on the upper pan, the indicator will come to rest in an approximately vertical position, point down, which is used as the initial reading. When 150 grams is placed on the scale the needle swings approximately 90°. Hence, when a 100-gram weight is placed on the upper pan the scale will weigh between 0–50 grams. When a 50-gram weight is placed on the upper pan the scale will weigh from 50–100 grams, and when no weights are placed on the upper pan it will weigh from 100–150 grams in swinging through an arc of 90°.

Thus, in weighing a large number of briquettes it is first necessary to determine within what 50-gram range they will fall, and place the necessary weight on the upper pan. The briquettes to be weighed are then placed on the lower pan and the same is carefully released until the indicator comes to rest.

Calibration

If the scale is made according to the specified drawings, it may be adjusted by moving the weights up or down on the levers until the following

conditions of equilibrium are reached: The indicator should be approximately vertical when a 100-gram weight is placed on the pan; with 125 grams, it should swing 45°, and with 150 grams it should come to rest in a horizontal position, *i. e.*, 90° from the vertical. The scale is then calibrated into 0.1 gram divisions by placing weights on the pan and marking the different positions on the scale indicated by the needle.

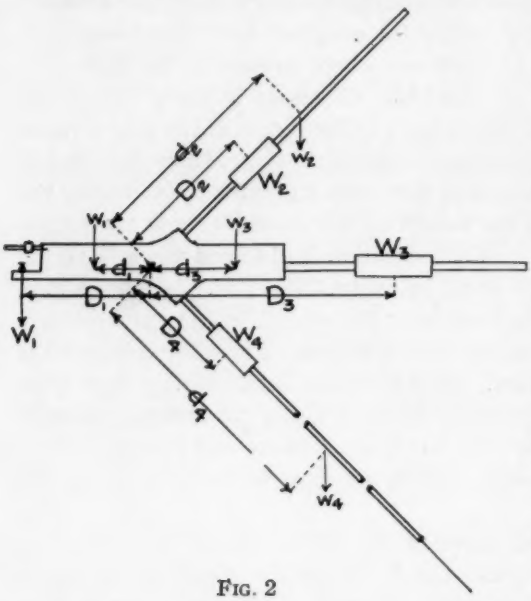

FIG. 2

The three positions of equilibrium, cited above, may be expressed by the following three equations. The significance of $W_1 \ldots W_4$ and $D_1 \ldots D_4$ is given in Figure 2. $w_1 \ldots w_4$ represent the weights in grams of the levers to one side of the main knife edge, respectively, $d_1 \ldots d_4$ represent the distances of the centers of gravity of $w_1 \ldots w_4$ from the main knife edge.

(1)

$$(W_1 + 100)\sqrt{\frac{D_1^2}{2}} + w_1\sqrt{\frac{d_1^2}{2}} = W_2D_2 + w_2d_2 + W_3\sqrt{\frac{D_3^2}{2}} + w_3\sqrt{\frac{d_3^2}{2}}$$

(2)

$$(W_1 + 125)\,D_1 + w_1d_1 = W_2\sqrt{\frac{D_2^2}{2}} + w_2\sqrt{\frac{d_2^2}{2}} + W_3D_3 + w_3d_3 + W_4\sqrt{\frac{D_4^2}{2}} + w_4\sqrt{\frac{d_4^2}{2}}$$

(3)

$$(W_1 + 150)\sqrt{\frac{D_1^2}{2}} + w_1\sqrt{\frac{d_1^2}{2}} = W_4D_4 + w_4d_4 + W_3\sqrt{\frac{D_3^2}{2}} + w_3\sqrt{\frac{d_3^2}{2}}$$

Since all of the above values are constant for a given design except D_2, D_3, and D_4, these values may be calculated from the above equations. If these distances are too small or large for this design, the values W_2, W_3, and W_4 may be increased or decreased as is found necessary.

If it is desired to change the capacity and accuracy of this scale, it is simply necessary to insert new values for 100, 125 and 150 grams in equations 1, 2, and 3, respectively, and calculate the distances D_2, D_3,

and D_4. For example, if it is desired to change the scale so that it will weigh up to 15 grams with an accuracy of 0.005 gram for 5-gram intervals, the values 10, 12.5 and 15 should be substituted in equations 1, 2 and 3, for 100, 125 and 150, respectively, and the new distances D_2, D_3, and D_4 calculated. While the writer has worked only with a scale of 150-gram capacity and an accuracy for 0.05 gram, and has not determined how much the capacity and accuracy may be changed, theoretically it seems possible to vary these within wide limits by the above method.

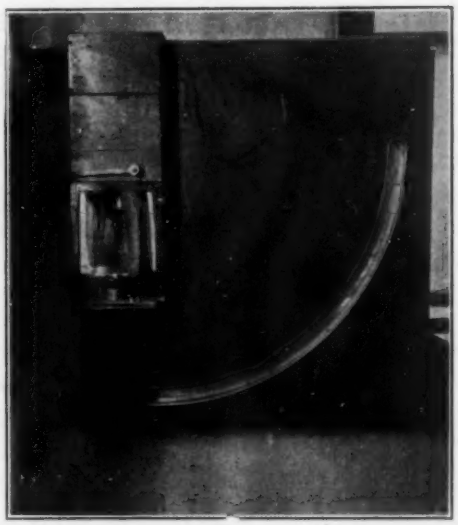

FIG. 3.—Exterior view.

Results

Where a large number of briquettes are to be tested it was found that they can be weighed on the automatic scale in about one-third the time required with balances having automatic attachments. This apparatus is expensive, costing approximately $200, but if used extensively, would soon pay for itself in the time saved. If it were made on a commercial basis, the price could be reduced considerably. To the amateur the trouble due to vibrations of the indicator before it comes to rest would be objectionable. This, however, may be largely overcome by careful manipulation. It has also been suggested that the time of vibrating of the indicator may be reduced by damping between two magnets placed in the path of the indicator.

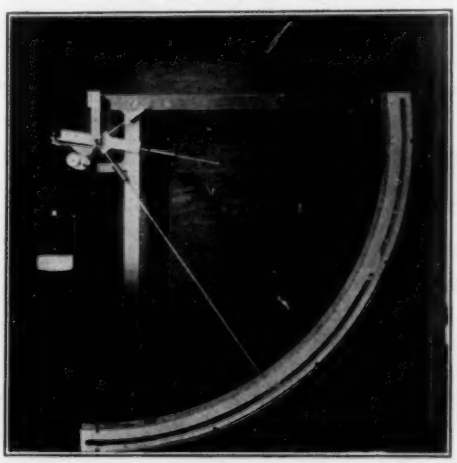

FIG. 4.—Interior view.

In conclusion, the writer wishes to acknowledge his indebtedness to Mr. R. T. Stull for helpful suggestions on this work.

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COMPOSITION AND PROPERTIES OF DIASPORE, BAUXITE AND GIBBSITE[1]

By Raymond M. Howe and R. F. Ferguson[2]

Bauxite has been used in the manufacture of refractories for many years and has given very good satisfaction under certain conditions. Aubrey and Greaves-Walker[3] state that bauxite bricks give unusually good service in the metallurgy of iron, lead and copper, and in Portland cement kiln linings. Any dissatisfaction has usually resulted from its high shrinkage, which is difficult to remove in the kiln.

More recently diaspore has been used in the manufacture of refractories, although this material has previously been rejected in the mining of fire clay. Diaspore apparently has less fire shrinkage than the other hydrates of alumina and in that way has a marked advantage.

Before discussing the properties of the various hydrates of alumina, the writers wish to summarize as briefly as possible certain articles which refer to their constitution, composition, color, hardness, specific gravity and fusion points.

Dana[4] and Lienau[5] divide the hydrates of alumina into three classes, the mono-, di-, and trihydrates. These correspond to water contents of 12% to 14%, 20% to 24% and 27% to 35%.

Berthier[6] regards the dihydrate as the true bauxite, for the material coming from the district of Les Baux corresponds most closely to this formula. Treadwell[7] apparently is of the same opinion for he gives the composition of bauxite as $Al_2O_3.2H_2O$.

Cornu and Redlich[8] consider only two hydrates, the mono- and trihydrates, and maintain that the dihydrate is a mixture of the others. Arsandaux[9] arrives at the conclusion that the silica in bauxite is introduced as clay substance more often than as quartzite. He also states that the iron occurs as the oxide and not as the hydrate. Berthier[10] concurs in the latter conclusion.

Wohlin[11] has undoubtedly completed the most thorough study of the constitution of the hydrates by making thermal analyses of sixteen samples.

[1] St. Louis Meeting, Feb., 1922.

[2] Fellows, Refractories Manufacturers Association Fellowship No. 5, Mellon Institute of Industrial Research, Pittsburgh, Pa.

[3] A. J. Aubrey, *Electrochem. Met. Ind.*, **4**, 466 (1907); A. F. Greaves-Walker, *Trans. Amer. Ceram. Soc.*, **8**, 297 (1906).

[4] Dana, "A System of Mineralogy," Wiley and Sons (1911).

[5] H. Lienau, *Chem. Zeit.*, **27**, 422 (1903).

[6] Berthier, *Annales des mines*, **6**, 531 (1831).

[7] Treadwell, *Kurzes Lehrbuch der analytischen Chemie*, **90** (1911).

[8] Cornu and Redlich, *Zeitschrift für Chemie u. Ind. der Kol.*, **4**, 90 (1908).

[9] Arsandaux, *Compt. rend.*, **138**, 936 (1909).

[10] *Op. cit.*

[11] Wohlin, *Sprechsaal*, **46**, 719 (1913).

These samples were heated in a small resistance furnace operated under standardized conditions. The temperature of the samples was slightly lower than that of the furnace except when some decided constitutional change occurred as the temperature increased. When bauxites of the mono-hydrate type were heated they showed a decided heat absorption at 540°C while they were being dehydrated. Those of the trihydrate type showed a heat absorption at 310°C, which was their dehydration temperature. The minerals which had a composition corresponding to a dihydrate showed heat absorptions at both 310°C and 540°C. He considered that this proved that the dihydrate was simply a mixture of the other two forms, thus confirming the conclusions of Cornu and Redlich.

Wohlin also observed that there was an evolution of heat at 1070°C. This was so pronounced that the temperature of the sample exceeded that of the furnace in which it was being heated by 40°C. This was associated with a marked increase in the density of the samples, for the specific gravities increased from 3.03 to 3.70 during this action.

Klockmann[1] gives the following ranges for the composition of bauxites:

Ignition	12 to 40%
Silica	2 to 30%
Alumina	50 to 70%
Ferric oxide	3 to 25%

With these oxides are associated about 3% of titania, which appears to be characteristic.

Other data given by Dana[2] are as follows:

Diaspore: $Al_2O_3.H_2O$; Al_2O_3 85.0 + H_2O 15.0 = 100.0; specific gravity = 3.3–3.5; color—whitish, grayish white, greenish gray, hair brown, yellowish to colorless; hardness = 6.5–7.0.

Bauxite: $Al_2O_3.2H_2O$; Al_2O_3 75.2 + H_2O 24.8 = 100.0; specific gravity = 2.55; color—whitish, grayish, to ocher yellow, brown and red.

Gibbsite: $Al_2O_3.3\ H_2O$; Al_2O_3 65.4 + H_2O 34.6 = 100.0; specific gravity = 2.3–2.4; color—white, grayish, greenish or reddish white; hardness = 2.5–3.5.

Bricks made from bauxite fuse at from 1565°–1785°C.[3]

The terms diaspore, bauxite and gibbsite as defined by Dana will be used in describing the experimental data recorded in this paper, although Wohlin undoubtedly proved that bauxite is a mixture of the other two hydrates. The present investigation was planned in order to study the relationship between chemical composition, refractoriness, fire shrinkage, and change in porosity. The usual standard methods were employed in making the tests and will not be described.

[1] Klockmann, *Lehrbuch der Mineralogie*, 406 (1912).

[2] Dana, *op. cit.*

[3] Kanolt, *Trans. Amer. Ceram. Soc.*, **15**, 167 (1913).

Composition of Diaspores, Bauxites and Gibbsites

The materials used in the present investigation gave the following ranges in composition. Their complete analyses are given in Table I.

Ignition	9.88–28.08
Silica	1.36–20.50
Alumina	52.48–73.70
Ferric oxide	0.47–23.55
Titania	2.09–3.85
Lime	0.22–3.17
Magnesia	0.16–0.79
Alkalies	0.37–1.34

TABLE I

COMPOSITION OF DIASPORES AND BAUXITES

	1	2	3	4	5	6	7
H_2O	28.08	17.90	13.74	13.14	9.88	14.98	14.24
SiO_2	9.70	18.90	13.96	20.50	1.36	17.84	5.36
Al_2O_3	56.31	52.48	67.21	60.89	60.66	61.98	73.70
Fe_2O_3	3.10	4.39	.75	.55	23.55	.47	2.28
TiO_2	2.09	2.68	3.22	3.14	3.85	2.85	3.57
CaO	.22	3.17	.22	.43	.22	.22	.40
MgO	.52	.40	.36	.31	.50	.79	.16
KNaO	.49	.43	1.16	1.34	.37	.38	.53
Total	100.51	100.35	100.62	100.30	100.39	100.51	100.24

It was observed that the usual standard method for analyzing clay was not entirely satisfactory for analyzing diaspore. This material is difficult to fuse with sodium carbonate and often considerable alumina remains with the silica residue. The carbonate fusion was, therefore, dissolved in hydrochloric acid and the insoluble residue filtered off. This residue and paper were then ignited and fused with potassium bisulfate. This cake was added to the original filtrate and the silica determined in the usual manner, care being exercised to correct the silica with hydrofluoric acid.

While the precautions involve considerable extra care and time they are deemed necessary, since the chief difference in the composition of clay and diaspore lies in their silica contents.

In reviewing the results it is to be noted that the alkalies, magnesia and characteristic 3% of titania show little variation. This is also true of the lime, except in one case where the bauxite was probably contaminated in mining by the limestone with which it occurred. The ignition losses, silica, ferric oxide, and alumina varied considerably. Sample No. 5 with its low ignition loss confirms Arsandaux's theory that the iron is present as the oxide and not as the hydroxide.

Fusion Points

There was an eight cone range in the fusion points of the minerals, the minimum being cone 34. (See Table II.) By taking samples 3 and 7, which are highest in alumina content and fusion point, and using them as a standard, certain general conclusions can be drawn regarding the relationship between composition and fusion point.

TABLE II
GENERAL DATA FOR BAUXITE AND DIASPORES

	1	2	3	4	5	6	7
Fusion points in cones	41	34	42	40	42	40	42
Per cent volume drying	...	...	...	...	...	...	...
Shrinkage	8.3	5.5	11.6	5.8	8.4	3.7	10.2
Porosity Cone 3	59.6	47.1	45.4	40.3	53.1	48.0	49.0
Porosity Cone 18	42.9	31.7	38.8	36.7	8.9	31.8	46.3
Difference	16.7	15.4	6.6	3.6	44.2	16.2	2.7
Burning shrinkage to Cone 3	18.0	12.7	8.2	12.2	12.2	16.7	1.3
Burning shrinkage to Cone 18	42.6	30.8	29.9	16.3	55.2	38.2	16.3
Difference	24.6	18.1	21.7	4.1	43.0	21.5	15.0
Per cent H_2O	28.08	17.90	13.74	13.41	9.88	14.98	14.24
Per cent SiO_2	9.70	18.90	13.96	20.50	1.36	17.84	5.36
Per cent Al_2O_3	56.31	52.48	67.21	60.89	60.66	61.98	73.70
Per cent Fe_2O_3	3.10	4.39	.75	.55	23.55	1.47	2.28
Source	Ark.	France	Mo.	Mo.	France	France	Mo.

When Nos. 3 and 4, and 6 and 7, are compared it is demonstrated that 10% of silica lowers the fusion point about 2 cones, for each of these sets of samples is remarkably similar otherwise. No. 5 shows that high iron (23.55%) does not lower the fusion point seriously when the sample is low in silica (1.36%). No. 2 would naturally fuse at about cone 40 but the high lime content (3.17%) has lowered its fusion point to cone 34. Thus, lime appears to be the worst flux in aluminous minerals; iron oxide is not a serious flux when the silica content is low and silica exerts a mild fluxing action when the iron oxide is low.

Porosity and Volume Changes

The results of the draw trial tests are given in Table III and IV. When these data are examined it is to be noted that there is a close relationship between the changes in porosity and the volume shrinkage. The average volume shrinkage from cone 3 to cone 18 was 22.6%; 15.0% was due to a decrease in porosity and 7.6% was due to an increase in the density of the substance.

There was only a rough relationship between the ignition losses and the volume shrinkages. Two samples had a very pronounced tendency to shrink—one was very high in ferric oxide (23.55%) and the other had a

TABLE III
BURNING SHRINKAGES AT VARIOUS TEMPERATURES

Cone	Temperature °C	Burning shrinkage by volume 1	2	3	4	5	6	7
01	1050	..	.0	8.1	12.7	9.3	..	.7
1	1100	..	4.6	8.2	12.5	11.8	..	.8
3	1150	18.0	12.7	8.2	12.2	12.2	..	2.6
6	1200	27.2	18.1	8.2	12.1	16.5	18.7	2.6
8	1250	33.0	23.0	10.6	14.3	37.6	20.7	4.0
10	1300	35.6	23.9	13.6	15.0	39.6	25.9	5.7
12	1350	40.1	30.0	16.7	15.8	41.6	26.5	9.2
14	1400	41.6	30.6	21.4	16.6	43.8	29.8	9.4
16	1450	42.4	31.5	28.6	16.6	55.4	35.3	12.4
18	1500	42.6	30.8	29.9	16.3	55.2	38.2	16.3

TABLE IV
POROSITIES AT VARIOUS TEMPERATURES

Cone	Temperature °C	1	2	3	4	5	6	7
01	1050	..	46.3	44.9	39.7	53.9	..	49.4
1	1100	..	47.5	44.6	40.1	53.2	..	48.6
3	1150	59.6	47.1	45.4	40.3	53.1	..	49.0
6	1200	54.6	42.0	43.8	37.1	49.0	47.6	49.5
8	1250	51.2	38.2	42.4	38.7	38.4	46.3	49.5
10	1300	50.0	38.6	41.5	38.3	36.4	43.8	49.1
12	1350	45.7	33.8	40.9	37.9	34.3	43.5	48.2
14	1400	44.5	32.8	39.4	35.1	31.9	40.5	48.9
16	1450	43.3	31.7	40.4	36.6	16.0	35.4	47.7
18	1500	42.9	31.7	38.8	36.7	8.9	31.8	46.3

high ignition loss (28.08%). These results lead to the conclusion that diaspores low in ferric oxide and containing several per cent of silica will shrink the least. Gibbsites high in ferric oxide and low in silica will shrink the most.

There was no apparent relationship between composition and drying shrinkage.

Summary

High alumina brick may be made from three ores, diaspore, bauxite and gibbsite. Diaspore is the monohydrate, gibbsite the trihydrate, and bauxite is a mixture of the two. These ores vary considerably in chemical composition except in magnesia, alkalies, and titania. Their fusion points are lowered most by lime and least by ferric oxide and silica. The burning shrinkages of the minerals high in silica were lowest, while those high in ferric oxide shrunk the most. Gibbsite had a higher burning shrinkage than diaspore.

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DIASPORE CLAY OF ARKANSAS AND MISSOURI[1]

By D. C. Wysor

Slightly less than a decade ago I spent about two years in the Arkansas bauxite fields. While there I had occasion to make a great many chemical analyses of the various grades of ore. During the course of operations I made, so far as I am aware, the first discovery of diaspore to be reported in this country. In 1915, I believe it was, I sent a short technical paper on this subject to economic geology. Arkansas diaspore exists in certain of the bauxite oölites only and probably constitutes not over 1% of the deposits. It is only of mineralogical interest. The rest of the hydrate composing the ore bodies is of the tri- or gibbsite type. You are, of course, familiar with the origin of the term bauxite, and know that it is generally applied to the ores of aluminum.

By very careful means of separation a few ounces of diaspore and diasporitic oölites were separated from time to time. Complete analyses of these were made and recast into corresponding mineralogical percentages with highly satisfactory results. These were grouped into a series showing on the one end practically pure diaspore and on the other essentially pure gibbsite. The question as to whether bauxite as a separate mineral actually existed was indeed puzzling. As such, certainly it cannot be recognized in Arkansas, and, so far as I know, it has never been isolated. However, I have always held that it did exist in Arkansas, at least, because we are reasonably certain that the diaspore there is subsequent to the gibbsite, having resulted from it through that metamorphic process characteristic of the higher hydrates of aluminum. And it seems only logical to me that in Nature's process of reduction from the tri- to the mono-hydrate, only one molecule of combined water would be lost at a time. I readily grant that the di-hydrate might be a very unstable compound that would probably serve only in the transition stage.

As indicated, therefore, diaspore appears to be a more stable compound than gibbsite, and if there is any bauxite mining going on in Arkansas 10,000,000 years from now, I have no doubt but that the hydrate produced will be, in reality, diaspore.

In passing I might say that the Arkansas diaspore has about the hardness and specific gravity that Dana[2] gives to the crystalline mineral, but, unlike the latter, it is amorphous. It is also accompanied by a high percentage of iron and titanium.

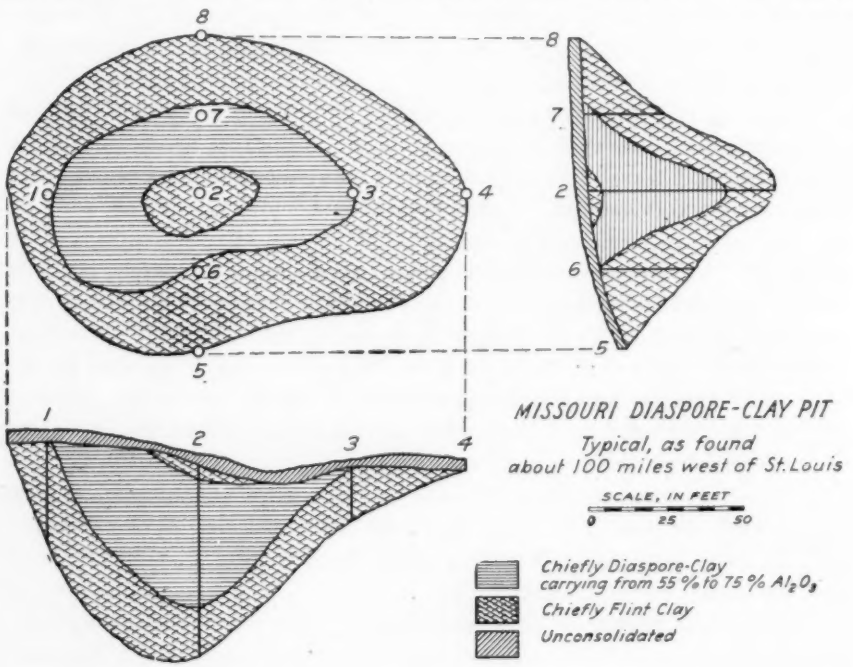
The commercial deposits of diaspore of Missouri, I think, are not at all similar in point of origin to the mineralogic diaspore of Arkansas. In Missouri I feel that we must look to some form of sedimentation. Diaspore here is always associated with these carboniferous flint or semi-

[1] Received July, 1922.

[2] Dana, *op. cit.*

flint clays, which, as you know, occur in well defined kettle shaped depressions. My idea is that the clay was deposited as a soft sediment (probably I should say a mechanical sediment) and the diaspore resulted from it during the period of solidification. I do not wish to discuss the point as to where the clay came from or how a normal aluminum silicate can be converted into a monohydrate. I shall leave it to the other fellow to prove that I am wrong.

Commercial quantities of diaspore in Missouri are found in a very limited number of these pits. No pit will ever consist of diaspore alone, although in some cases this material will make up the bulk of the core. It is always



surrounded by the clay. As a rule the diaspore is more or less stratified in the deposit, a normal succession being: Clay, low grade diaspore, high grade diaspore, low grade diaspore, clay, low grade diaspore and so on. Every gradation can be found between clay and diaspore carrying 80% alumina (85% Al_2O_3 is the theoretical limit). In mining practice, two or three grades, depending upon alumina content, can be readily distinguished.

Missouri diaspore is of several distinct types physically. With certain minor exceptions all appear to be amorphous. Even so, there must be some difference in the arrangement of the atoms of the molecules as between Missouri and Arkansas diaspore. A certain acid treatment which readily dissolves Arkansas diaspore has little effect on the Missouri member.

As stated above, the accessory constituents iron and titanium, are high in case of Arkansas diaspore. In Missouri, the iron is low, titanium is fairly high with the other accessory components rather normal. The highest grade material which I found in Arkansas would compare about as follows with the normal Missouri product.

	Arkansas	Missouri	(Pure dias.)
H_2O	14.00	13.50	15.00
Al_2O_3	71.00	65.00	85.00
SiO_2	1.00	15.00	...
TiO_2	5.00	4.00	...
Fe_2O_3	9.00	1.20	...
CaO	...	.10	...
MgO	...	.20	...
K_2O and Na_2O	...	1.00	...
	100.00	100.00	100.00

All of the silica in the Arkansas type is in the combined state as in a kaolinitic variety of clay which accompanies the deposits. Under normal conditions there is little or no free silica present in Missouri diaspore. The silica present is in the associated flint or semi-flint clays.

Missouri diaspore of the composition as above given will fuse at cone 38 or 39. Material carrying 70% to 75% alumina should fuse at cone 41 or thereabouts. A 55% diaspore will fuse at about cone 37. There seems to be about one cone of difference for each 4 or 5 per cent alumina, but of course the actual fusion point is influenced by the relative proportions of the respective accessory constituents. The highest grade bauxite will probably fuse at cone 39 to 40.

I have seen diaspore from a number of other localities in the United States that resembled the Missouri material, but so far as I am aware Missouri is the only place in America, and probably the only known place in the world, where high grade diaspore could be mined and shipped in appreciable commercial quantities. At best any diaspore is comparatively rare. It is possible to select specimens of Missouri diaspore carrying 80% or more alumina, but shipments carrying 70% to 75% alumina are about the highest grade practicable to attain. Such a product as this is very rare. Fifty to 60% ore is much more abundant.

That Missouri diaspore is becoming rapidly more popular in the refractory field is evidenced by the much larger tonnages now being consumed. That it is superior to bauxite in the manufacture of refractories I think there can be no doubt. The higher refractoriness which can be obtained and the lower shrinkage of the diaspore are certainly strong points in its favor. Diaspore carrying 9% or less silica appears to be in greater demand than bauxite in the abrasive industry.

Further Discussions on Diaspore

By D. C. Wysor[1]—A Missouri diaspore-clay deposit, or pit as we may choose, typical as to size and shape and as to quality of material, might be briefly summarized as follows:

Surface diameter, 75 to 250 feet, average about	125
Maximum depth, 50 to 150 feet, average maximum about	60
Average depth of average pit about	25
Average tonnage of average pit about	15,000

divided probably about as follows:

Smooth clay (chiefly flint with some bond)	8,000
Abrasive grade diaspore (70% Al_2O_3 and 10% or less SiO_2)	250
No. 1 grade diaspore (65% Al_2O_3 and 15% SiO_2)	750
No. 2 grade diaspore (60% Al_2O_3 and 20% SiO_2)	2,000
No. 3 grade diaspore (55% Al_2O_3 and 25% SiO_2)	4,000

These relative tonnages will, of course, vary greatly from point to point. Probably the majority of diaspore pits have little or no abrasive grade that can be selected in commercial quantities. In exceptional cases, however, the abrasive type may constitute a considerable proportion of all the diaspore in the deposit, though the No. 2 and No. 3 always predominate.

The above grades, with their respective standards of quality, I have originated for practical convenience. The term "Burley" Clay, which I do not like because of its loose usage, is generally applied in this section, as you no doubt know, to clay carrying around 45% to 50% or possibly 55% alumina. The No. 3 grade will fuse at about cone 37, while the abrasive grade will fuse around cone 42. The best grade flint clay in this section will fuse at cone 34.

A diaspore-clay pit is usually roughly elliptical. The deepest part of the pit is seldom in the center, but often about half way between the center and one side. As a result of this eccentric condition, the wall on one side of the deposit will dip very steeply (probably as much as 90 degrees at the surface) while on the opposing side of the deposit, a gentle slope of 20 to 25 degrees may be encountered.

The wall rock of all of the pits in this section is sandstone, which is loosely cemented. In some cases where the sandstone is very argillaceous and badly weathered, it amounts to nothing more than a soft impure clay which may cause considerable trouble by caving during mining operation.

The diaspore-clay pit, then, can best be realized as a kettle shaped mass bounded at all points of contact with sandstone. The surface of the pit will be covered, on an average, with about four feet of soil, sand, gravel or residual chert and hardpan. The gradation between the sandstone wall

[1] Received November, 1922.

and the flint clay, which always forms a shell from 5 to 20 feet or more in thickness about the diaspore core, is generally sharp, though it is often gradual on one side of the deposit and sharp on the opposing side.

Within this shell of flint clay will be found any or all of the above mentioned grades of diaspore together with some layers of flint and bond clays. The entire mass is usually roughly stratified. The gradation between the various grades of diaspore and clay is often fairly sharp, but generally it is gradual.

Diaspore Clays of Missouri

By I. A. Krusen:—This discussion will be limited to the east-central district of Missouri, producing only non-plastic or flint fire clays. Roughly speaking, this district is circular with a diameter of about 25 miles including the following towns: Belle, Owensville, Lesley and Cuba.

The deposits are not confined to a particular geological horizon or period occurring in or on rocks of the Pennsylvanian, Ordovician, Silurian and Mississippian formations. They do not occur as stratified beds but as massive deposits filling the crater-like depressions in the sandstone or limestone. These basins occupied by the flint clay vary from 50 to 250 feet in diameter, and from 15 to 100 feet in depth.

The total number of these pits has been estimated at 7,000. About 200 of this number have been worked. They are estimated to average from 5,000 to 10,000 tons in each pit, although some contain as much as 100,000 tons. About $^1/_4$ of this area contains pits furnishing diaspore. There is a great variation in size of pits and content of each. The following worked-out pit may give some idea. It contained 5,000 tons divided as follows: 2,000 tons of smooth flint, 2,500 tons of burley flint and 500 tons of diaspore. These three divisions of flint clay occur as follows:

Smooth flint—found alone, with burley or both burley and diaspore.
Burley flint—found either with smooth or with both smooth and diaspore.
Diaspore—combined with both smooth and burley.

Flint clay mining is carried on by the open pit method. The over burden which is not usually over 5 to 15 feet is stripped back by teams and scrapers exposing the top of the flint. It might be of interest to note that the first layer or lining of the bowl or pocket is always smooth flint, varying from 2 to 4 or more feet in thickness, the balance of the deposit sometimes containing burley or both burley and diaspore.

The flint clays usually are very pure chemically, have a compact dense structure and break with a sharp conchoidal fracture. When ground and mixed with water they have little plasticity. The following is a typical analysis of the smooth flint:

Silica	44.02	Calcium	trace
Alumina	40.06	Magnesia	.11
Iron oxide	.49	Alkalies	.45
Titania	1.65	Loss on ignition	13.46
		Total	100.24

The smooth flint clays will soften from cone 34 to 35.

Air shrinkage	5%
Burn shrinkage	5%

This flint is used together with plastic fire clay in high grade fire brick and some fire clay shapes.

Burley flint is rougher, has a higher fusing point, and is in general a better refractory. The following analysis shows a typical burley flint:

Silica	30.46	Magnesia	.20
Alumina	54.09	Alkalies	.50
Iron oxide	1.35	Ignition	12.95
Lime	1.37	Total	100.92

It has a fusing point of cone 36 or better. Both the flints have a high shrinkage. Burley flint is used in high grade refractory brick and tile.

The most recently discovered and important associate of the flint clay is diaspore clay, a variety rich in alumina, formerly discarded because of its rough ashy texture. The presence of this rough type of clay has until recently been regarded as detrimental or worthless and today some abandoned pits may be found where large bodies of it were left. The peculiar texture of the diaspore clay and its common association with the flint clay, frequently as a core near the center of the deposit or as rounded boulders in the overlying weathered clay, aroused the interest of W. S. Cox of Cuba, Missouri, who had for several years been a producer of flint clay. Probably it is through his interest and work that we are indebted for the important part this clay is fast assuming in the refractories and other industries of today.

Diaspore clay is found in the flint area extending from a few pits around Gerald to more numerous deposits located around Owensville and Belle. Most of the clay shipped has been taken from the above described country and within a distance of three or four miles from the Rock Island Railway which traverses this district.

A few deposits have been located at Cuba and shipped via the Frisco Railway. It is not improbable that other deposits will be discovered and worked as the higher price obtained for this clay permits of a much longer haul to the railroad.

An average analysis is as follows:

	Average	High Al_2O_3
Ignition	13.70	14.84
Silica	12.72	2.80
Alumina	68.39	78.30
Iron oxide	1.05	1.26
Lime	.20	.20
Magnesia	.12	.30
Titania	3.80	3.80
Total	99.98	101.50

As a general rule the diaspore clay is located in the center of the pit much like the yolk of an egg.

The structure of a deposit is very similar to an egg. The rim rock or outside shell is usually sandstone, and surrounds a layer of white flint extending from a few feet in thickness to a solid deposit of flint. Inside the flint wall is found the burley clay and diaspore, usually in layers varying in thickness from a few inches to ten or more feet. These layers seldom lie on a horizontal plane but usually tilt at an angle from a few degrees to almost perpendicular. In some instances smooth clay is also found between layers of diaspore or diaspore and burley.

The tonnage of diaspore found in the different pits may be as low as 100 or it may reach 10,000 to 20,000 tons in a few cases.

Discussion[1]

R. M. HOWE:—This subject has attracted considerable interest recently and I would like to hear about the occurrence of diaspore in the flint clays of Pennsylvania.

A. F. GREAVES-WALKER:—The occurrence of high alumina clays and burley flint clays in Kentucky and Pennsylvania, especially in Kentucky, are very similar to the formations in Missouri, except that the lenses of clays in the Eastern states are tremendously large as compared with Missouri. In northeastern Kentucky, in one or two instances where the occurrence of this clay was noted, the deposits were exactly the same as the Missouri diaspore clay, occurring in the center of a very large lens.

The deposits are the shape of an egg, that is, small at the top, then enlarging and tapering towards the bottom; the shell of the egg-shaped diaspore deposit is sandstone. Inside of this sandstone shell, or as we call it, the rim, because it appears on the surface as a rim of rick, comes the white flint clay—positioned similarly to the white of the egg, and in the center comes the diaspore like the yellow of the egg. I do not know about Pennsylvania but I presume the deposits are very much the same.

[1] Refractories Division, St. Louis meeting, Feb., 1922.

J. S. McDOWELL:—So far as I have been able to observe, there is no similarity between the diaspore occurrences in Pennsylvania, or rather, the nodular clay, and the diaspore clay in Missouri. The occurrences of this nodular clay have been known for a great many years. Prior to 1900 it was not used; on account of its rough appearance, it was considered poor clay and thrown away. Early in this century the fact was discovered that it really was of exceptionally good quality and the mine owners went over the old gob piles and recovered the nodule clay.

A great many of the mines in Clearfield County contain more or less nodule clay. In certain districts the nodule seems to occur about the center of the bed, but in other areas it is at the top. In the nodule clay the alumina content will vary from about 38 to a little over 50%.

R. M. HOWE:—Do you regard the nodule clay of Pennsylvania as being similar in character to the burley clays and diaspore of Missouri?

J. S. McDOWELL:—The nodule clay resembles the burley clay more than anything else. I do not believe there was any suggestion until recently that the nodules might consist of diaspores but it is very probable that they do.

A. B. CHRISTOPHER:—In the vicinity of Owensville, Mo., diaspore clay occurs uncovered like big flat boulders; it is not necessary to dig at all, just break them up and load them on to wagons.

A. F. GREAVES-WALKER:—We found in Missouri diaspore deposits exposed by erosion. It occurred to me that possibly in Pennsylvania, after observing some of the Kentucky deposits, the same thing had occurred, where these deposits are exposed, that the top deposit of clay may have been eroded away, bringing the nodular clay to the top. The boulder deposits in Missouri are the result of the weathering of the deposits that have been eroded at the top. If these deposits run as high as 80% alumina they do not weather very rapidly, but if they get below 60% they weather comparatively fast; therefore, when weathering takes place on the surface of one of these deposits of mixed high and low grade material, the low grade diaspore disappears leaving the high grade boulders on top, as they are extremely hard and resist the weather.

I should like to ask Mr. Howe if he has information on the effect of titania on the melting point and vitrification.

R. M. HOWE:—While I have no definite information regarding the fluxing power of titania in diaspore, it would appear, by analogy, to be low. In the first place, alumina, iron oxide, and titania are very closely related from a chemical standpoint. It is also known that titania is a mild flux in clays, but that its activity is less in those of the higher alumina content. One per cent of titania is capable of lowering the fusion point of normal clay only $^1/_2$ cone and, consequently, would lower the fusion point of commercial diaspore scarcely more than $^1/_4$ cone, the amount depending upon the silica and flux content.

So far as vitrification is concerned, it should be borne in mind that very open burning flint clays carry as much, or even more titania, than the dense burning plastic clays; consequently its action is no different than that of any other flux. Vitrification is probably more closely associated with certain physical properties, such as size of grain and plasticity.

A MEMBER:—Does repeated firing at high temperature cause continued shrinkage?

R. M. HOWE:—Before answering that, I wish to ask which material you have in mind in your question?

A MEMBER:—Either material, diaspore or gibbsite.

R. M. HOWE:—It is extremely difficult to completely remove the shrinkage of gibbsite. With its high water content a great many pore spaces remain to be filled by the shrinkage of the clay. It is necessary to raise it to a temperature higher than that at which it will be used if shrinkage in service is to be avoided, utilizing perhaps an electric furnace.

The shrinkage of diaspore is less than that of gibbsite as might be expected from its lower water content. It seems to depend also upon the silica, being low with high silica. No unconquerable difficulty should be experienced in the removal of shrinkage from this material.

THE EFFECT OF HEAT-TREATMENT AND COMPOSITION OF SEMI-PORCELAIN BODIES ON CRAZING

By Ira E. Sproat[1]

ABSTRACT

Limits of Investigation.—The investigation was confined to practical semi-porcelain bodies and glazes, therefore, the results may be applicable only to this branch of the whitewares industry.

Effect of Thickness of Glaze.—The thicker the glaze the greater the tendency to craze. The glaze on several pieces of dinner ware may appear to the eye to be of uniform thickness, but still have sufficient variation in thickness as to show difference in crazing behavior. It being impossible to obtain a uniform thickness of glaze by hand dipping there is a need for a mechanical dipper. An improved type of biscuit kiln which will produce ware with a uniform absorption is another need.

Effect of Glaze Composition.—When sufficient change was made in the composition of a typical semi-porcelain glaze to cause a marked decrease in its crazing tendency, it was at the expense of other desirable properties.

Effect of Body Composition.—The addition of 10.0% to 20.0% of "Hercules" clay to a general ware body greatly decreased its tendency to craze. No other change in body composition was found feasible, for when the change was sufficient to cause a decrease in the crazing it was at the sacrifice of other essential properties.

Effect of Variation in Absorption.—Contrary to the general opinion among potters, the tendency to craze was not increased by every increase in absorption. An absorption of about 7.0% to 12.0% showed the most resistance to crazing.

Effect of the Time-temperature of the Gloss Burn.—Tendency to craze is decreased by increasing the maturing time-temperature portion of the gloss burn.

Introduction

It is interesting, upon asking a group of practical potters regarding their opinion of the cause and cure of crazing, to note how divergent are the methods of attack employed, and how widely dissimilar are their points of view. A majority of the potters of a conservative turn of mind will insist that they are having little or no crazing, at the time expounding the merits of the present plant methods with a gravity matched only by their conviction that "all is well in the best of possible worlds;" a few will temper their seriousness with a burning irony, and others will issue a flaring challenge that will contrast vividly with the complacence of the majority, insisting that the time has come when the American potter must improve the quality of his ware.

Surely if any ceramic product should be free from crazing it ought to be the dishes on which is served our food; a seeming necessity from the standpoint of health, if for no other reason.

The results given in this report cover a period of three years of research and observation in some of the leading semi-porcelain factories in the country. The entire work was conducted under factory conditions and confined to practical general ware bodies and glazes. Therefore, it must

[1] Presented at St. Louis Meeting, February, 1922.

be remembered that the conclusions drawn from this series of investigations may only be applicable to this particular whiteware industry.

Thickness of Glaze

It is well known that the thicker the glaze the greater the tendency to craze, but there is very little information to be obtained from a study of the literature on the subject or from the experiences of the average potter, regarding the degree, to which the thickness of a glaze influences its crazing behavior. Therefore, it was thought best to give this problem first consideration as it may have marked influence on other factors affecting the crazing problem.

Preparation of Trials.—Sufficient clay to make 48 standard 5-inch plates (trade size) was taken direct from the pug mill and wedged by hand in order to assume a uniform body composition for the entire set of trials. The plates were jiggered, dried, and finished in the usual way, then fired in the same horizontal plane on the same car in the Dressler tunnel kiln to cone 8. The firing time was 96 hours and the average absorption of the trials was 8.9%. In order to be doubly sure that each plate would have the same absorptive power when dipped they were soaked in water for five hours and then wiped dry on the surface.

Seven glaze batches were made up weighing respectively 27, 26, 25, 24, 23, 22, and 21 ounces to the pint. Six plate trials, having previously been soaked in water, were dipped in each glaze, care being taken to dip each piece in the same manner. The plates were then gloss fired to cone 4 in the second ring of a periodic kiln. The time of firing was 24 hours. These trials were then tested for crazing.

Crazing Test.—In a prior investigation of various crazing tests, the following was found to give best and most consistent results, and therefore it was used throughout this series of investigations.

The trials were heated in an electric oven to 125°C, then quenched in ice water, this repeated three times to compensate for any uneven heat distribution within the oven. At the end of the three quenchings the plates were examined for crazing, and those that had not crazed were heated to 150°C and quenched three times. Likewise the trials not crazing at this temperature were heated to 175°C and quenched three times. Those trials not crazing at this temperature were tested at 200°C. The final treatment being at 225°C.

Results of Test.—The average crazing behavior of the six trials with seven weights of glaze is given in Table I.

It can readily be seen that a glaze may not appear to be too heavy nor too light but still vary in thickness to such a degree as to cause a decided variation in crazing. The facts bear sufficient witness that the thickness

of the glaze is a very important factor, and must always be considered in the control of crazing in the factory, as well as in the study of any crazing problem from a purely technical standpoint. In other words conclusions drawn from a series of crazing tests are valueless unless the thickness of the glaze is known to be the same throughout the experiment.

Specific attention is called to the fact that even after taking every precaution possible to produce a uniform thickness of glaze in each set of trials, there were six plates out of the 42 which did not show consistent crazing behavior. These results are noted under the heading "Remarks" in Table I. After examining under a microscope the thickness of the glaze on

TABLE I

No.	Weight of glaze, oz. to pt.	Crazed at	Appearance of glaze	Remarks
1	27	..	Very thick	Crazed when taken from kiln
2	26	125°	Heavy around foot	2 crazed before testing
3	25	175°	Good	2 crazed at 150°
4	24	200°	Good	
5	23	225°	Good	2 crazed at 200°
6	22	O. K.	Dry on edges	
7	21	O. K.	Very thin glaze Very dry	

these seeming erratic trials, and comparing it with that of the other plates in the same group, it was plain in five cases out of the six that the difference in crazing behavior in the same group could be attributed to a difference in the thickness of the glaze.

It was thought that inability to obtain a uniform thickness of glaze was possibly due to soaking the trials in water before dipping, therefore, a second test was made. This time two dozen 5-inch plates were fired in the same sagger in the third ring of a periodic kiln. The heat-treatment was cone 7, and the absorption 9.2%. These trials were not soaked in water but given to an expert dipper just as they came from the biscuit kiln. The dipper was given instructions to dip the two dozen plates in exactly the same manner. After gloss firing in the same sagger to cone 3, and testing for crazing we found that we had the same irregularity in thickness of glaze, with the resulting variation in crazing behavior, as we obtained in our first test.

The inevitable conclusion is that, due to the human element entering into the dipping process, it is impossible to produce ware with the same thickness of glaze even though it has the same absorption. When one considers the fact that under the best kiln conditions the absorption of the ware which goes to the dipper will vary from 6.0% to 11.0%, it is not surprising that in the average general ware plant the thickness of the glaze on the

ware varies from a very thin glaze, slightly dry on the edges, to a thick one which appears thick only around the foot.

When viewed solely from the standpoint of crazing it is far from good dipping, for the glaze should be uniform in thickness, and just as thin as it is possible to make it without showing dry edges or dry spots on any portion of the ware in order to produce a product with the least tendency to craze. Since these conditions are not possible under present day commercial methods of manufacture, what *is* the solution? How can the thickness be controlled?

An improved type of kiln that would produce dinner ware with a comparative uniform absorption, (2% max. variation) would be a great aid. If the hot zone of the Dressler tunnel kiln was increased 20 or 30 feet with an increase in the total length of from 50 to 75 feet, and the width of the tunnel decreased considerably, we would have a kiln that would closely approach the ideal. If 18 to 24 hours were added to the firing schedule of the ordinary periodic biscuit kiln, far better results would be obtained.

Another aid would be a mechanical dipper which would eliminate the human element from this important process. Such a device would make it possible to control the thickness of the glaze. The variable absorption of the ware could be overcome by passing the ware through water before it entered the dipping machine. Five minutes before a modern printing press or a cigar machine, or hundreds of other mechanical accomplishments of the past decade, should convince one that such a simple operation as dipping dinner ware can be done mechanically and to perfection.

It seems to us that the mechanical dipper would be an ideal problem for coöperative research, and would do much for the advancement of the pottery industry. Such a machine would not only go a long way toward solving the crazing problem but would entirely eliminate a number of other vexing ills so prevalent in this industry, and directly or indirectly traceable to the dipping department.

With improved type of tunnel kiln capable of producing biscuit ware with a comparative uniform porosity, and mechanical dipper which would produce a uniform thickness of glaze are devices of the future. We hope that these mechanical problems will be taken up by the potteries in the near future and pushed to a successful conclusion. We feel that much stress has rightly been laid on the importance of the thickness of the glaze coating, and that it should receive careful study by every semi-porcelain manufacturer.

Glaze Composition

Since the rules formulated by Dr. Seger for decreasing crazing by changes in glaze composition have been generally accepted as reliable and are well

understood by the average potter, it is needless to consider this phase of the problem in this report. However, there is little published data regarding the effect such changes will have on other properties of the glaze, which must always be considered in the development of a good commercial semi-porcelain glaze. A glaze may be free from all defects but still could not be classed as a practical semi-porcelain glaze. A good practical glaze must possess the following properties, besides being free from defects:

1. Good fluidity from cone 1 to cone 6.
2. Maximum gloss at cone 1.
3. Must mature at cone 1 and show no signs of an egg shell texture at this heat-treatment.
4. Must not overfire at cone 6.
5. Must not pin mark in the decorating kilns at cone 012.

Details of Test.—The following practical semi-porcelain glaze was used as the basis for these tests:

0.027 Na_2O		
0.202 K_2O		
0.422 CaO	0.256 Al_2O_3	0.24 B_2O_3
0.213 PbO		2.354 SiO_2
0.136 ZnO		

Three series of ten glazes each were compounded as follows:—Series 1: the flint content of the base glaze was increased in increments of 0.075 equivalents. Series 2: boric acid was increased at the expense of the silica in increments of 0.03 equivalents. Series 3: barium carbonate was substituted for the white lead in increments of 0.01 equivalents.

All thirty glazes were weighed out separately and compounded so as to weigh 26 ounces to the pint. Ten 5-inch plate trials having been soaked in water for five hours and then wiped dry were dipped in each of the above glazes. All trials had the same absorption as if they had been fired in the same portion of the biscuit kiln. The glazed trials were dried and fired to cone 1 in the third ring of the gloss kiln; six of the fired trials from each glaze were then tested for crazing.

Stilt Marking.—The glazes were tested for stilt marking by placing a number of stilts on two trials from each glaze and firing them in the back top of a decorating kiln to cone 012.

Fluidity at Cone 1.—From lack of a better method the viscosity of the glaze was tested by scratching two of the trial plates of each glaze just after being dipped. Four marks or scratches, varying in width from a knife edge to one quarter inch, were placed on trials from the center to

the edge of the plates, care being taken not to move the plates after scratching until the glaze was dry.

The degree to which the glaze filled these cut places during the gloss fire at cone 1 was compared with similar trials made from the base glaze fired under the same conditions. In this way the relative fluidity of the test glazes was determined.

The principal property of a good commercial semi-porcelain glaze, aside from being free from defects, is its ability to flow at the minimum gloss heat. Good fluidity is absolutely necessary, for under present factory conditions of dipping, the glaze on a majority of the ware is cut by handling or is far from being uniform in thickness. In other words the glaze must have sufficient fluidity to cover up all minor defects in the glaze coating.

Summary of Results.—When sufficient change was made in the glaze composition to produce any marked decrease in crazing behavior, the glaze did not possess some of the other properties so essential to a practical commercial glaze. The glazes that showed the least tendency to craze were the high silica glazes, but these were too viscous and did not flow readily at cone 1.

The results of these tests made it evident that the fluidity of the glaze on one side and stilt marking on the other, determined to a large degree the possible variation in glaze composition. This probably explains why the glazes used by the leading general ware plants show but slight variation in molecular composition.

We do not wish to create the impression that a good practical glaze could not be compounded which would have a less tendency to craze than the base glaze used in this investigation. Quite to the contrary, we are of the opinion that we would have had better success, if we had continued this preliminary investigation in other directions.

Body Composition

A number of preliminary investigations of various changes in body composition were made, but as a detailed discussion of the results would only tend to obscure the main issue rather than to clarify, only a brief summary of the results will be given.

These tests plainly indicated that the composition of a practical semi-porcelain body was also limited by factory conditions just as was found in case of glaze composition. It was perfectly evident that under present day methods of manufacture in all the general ware industries in the United States (with the probable exception of one or two where quality and not quantity is the foremost consideration) the composition of the body is limited to comparatively narrow variations. This is due to the demand

for the whitest body possible with maximum strength in the clay state in order that it can be handled with speed without causing an excessive biscuit loss.

The color of the finished product and the transverse strength of the body in the clay state are the two paramount factors which make it very difficult to make sufficient changes in the percentage proportions of the usual raw materials to produce any marked decrease in the tendency to craze.

Investigations have shown that by the use of from 10.0% to 15.0% of a new clay from Missouri, sold under the trade name of "Hercules," a good practical body can be made free from crazing.

"Hercules" clay is neither a ball clay nor a china clay but a cross between the two. It has a modulus of rupture of 325 pounds per square inch, a drying shrinkage of 6.0% and a total shrinkage of 14.0% at cone 8. It has a silica content of 61% which explains its most remarkable property, that of decreasing crazing.

The effect of substituting "Hercules" clay for a portion of the ball clay and china clay in a semi-porcelain body is plainly shown in the investigation given below.

Composition of Bodies.—The percentage compositions of the bodies used in this series of tests are given in Table II. These bodies are all practical general ware bodies, and are being used today with marked success. The percentages given in Table II were figured from the scale weights, no allowance made for moisture.

TABLE II

Material	Body no. A	B	C	D	E
Flint	34.05%	32.16%	31.10%	32.44%	35.0%
Feldspar	14.00	14.20	12.50	13.77	14.5
Edgar's Florida kaolin	7.55	6.10	6.40	6.23	7.5
English china clay	27.35	24.30	23.70	19.67	14.0
English ball clay	17.05	16.20	13.80	14.80	8.0
Harris's N. C. kaolin	...	7.10	12.50	...	..
"Hercules" clay	...	...	...	15.09	21.0

Trials.—The trials used throughout this investigation were standard 4-inch plates, trade size. 500 were made from each body.

Biscuit Burn.—Eighty plates from each body were biscuit fired to each of the following heat treatments inside the sagger: cone 5, 6, 7, 8, 9, and 10. These six heat-treatments were chosen for two reasons: first, because they covered the maximum variation that would likely occur in the most erratic commercial kiln conditions and, second, the extremes were not too far from the field of good commercial practice as not to make the results especially applicable to the general ware industry.

Absorption.—The absorption of each body at the various biscuit burns was determined by soaking three trials from each body from each firing in water for 12 hours, and then boiling for 3 hours. The absorption being calculated in the usual manner from the dry and wet weights. The average of each set of three trials being taken as the absorption value of the series of trials to be used in later tests. These values are given in Table III.

TABLE III

Biscuit heat-treatment	Body A	B	C	D	E
Cone 5	13.0%	13.2%	14.2%	12.8%	12.6%
6	10.6	10.5	11.2	10.3	10.4
7	7.9	8.0	9.1	7.6	7.7
8	6.6	6.6	7.4	6.3	6.1
9	4.4	4.5	6.0	4.7	4.5
10	2.1	2.2	3.8	2.7	2.9

Dipping.—For the purpose of identification the cone to which each set of trials was fired was stamped with a cobalt stain on the back of each plate within the group. All trials were soaked in water for 12 hours, wiped off, and dipped in a regular commercial glaze weighing 25 ounces to the pint. The trials were then thoroughly dried before being gloss fired.

Gloss Fire.—A series of six plates from each body from each biscuit burn were gloss fired under the following 12 different heat-treatments:

a. Cone 1
b. Cone 5 } 18 hrs., periodic kiln, oil fuel.

c. Cone 1
d. Cone 5 } 24 hrs., periodic kiln, coal fuel.

e. Cone 1
f. Cone 5 } 30 hrs., periodic kiln, coal fuel.

g. Cone 1
h. Cone 5 } 40 min. schedule, tunnel kiln, producer gas.

i. Cone 1
j. Cone 5 } 50 min. schedule, tunnel kiln, producer gas.

k. Cone 1
l. Cone 5 } 60 min. schedule, tunnel kiln, producer gas.

Test for Crazing and Shivering.—After each trial was marked with its gloss heat-treatment it was set aside for three months. All the trials were then examined for crazing and shivering. The results of this examination at the end of the three months are shown in Fig. 1.

Those trials that showed no glaze defects after standing for three months were tested for crazing according to the standard test already described. The results of these crazing tests are given in Fig. 2.

From a study of the results in Figs. 1 and 2 from observations in several factories where "Hercules" clay is being used in their regular body, we can state without fear of successful contradiction that by the use of 10.0% to 20.0% of "Hercules" clay in the average semi-porcelain body, the tendency to craze can be greatly decreased under all conditions of biscuit and gloss heat-treatment. In fact it is possible to go from one extreme of crazing to the other extreme, that of shivering, by the simple procedure of substituting increasing amounts of "Hercules" clay in the body.

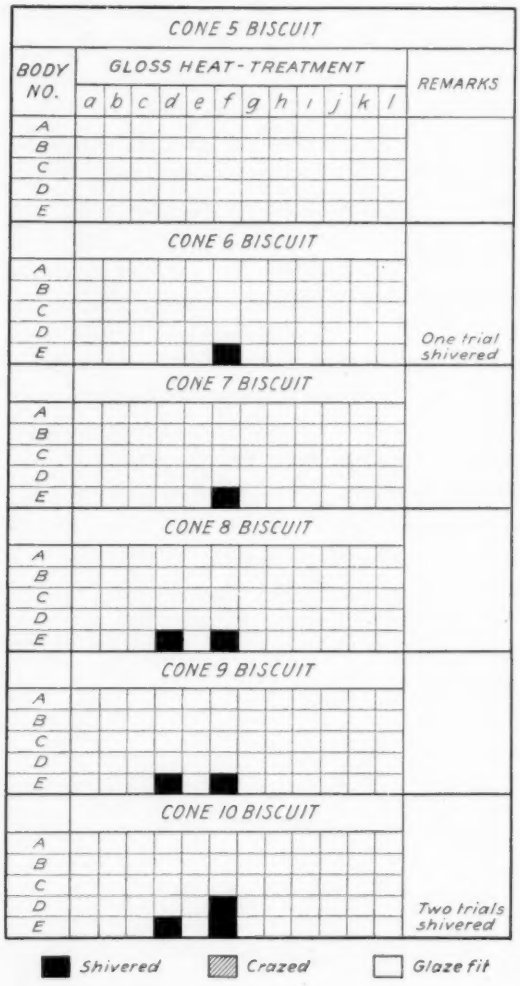


FIG. 1.

The data in Fig. 2 plainly shows that there is very little difference in the crazing behavior of bodies "*A*," "*B*," and "*C*," regardless of the fact that body "*A*" contained 1.89% more flint than body "*B*" and 2.95% more than body "*C*."

Shivering.—It will be noted that body "*E*" containing 21.0% of "Hercules" clay shivered when subjected to a high biscuit fire and a prolonged gloss fire. From observations during an extensive use of this body we found that if the gloss fire was prolonged over 24 hours this body showed marked tendency to shiver, especially the ware in the first ring which was subjected to the higher temperatures of the gloss fire. Very little shivering occurred in the ware fired in the third ring of the gloss kiln. The ware always cracked or shivered through its weakest point. A piece of ware with a thin section or an air bleb would shiver, while another piece not possessing these structural defects but fired under the same conditions could be made to shiver.

Another interesting feature of this shivering was the failure of the ware soon after being gloss fired. If a piece of ware shivered it invariably did so within three weeks from the time it was drawn from the kiln and no further shivering was induced in the subsequent heating and quenching test.

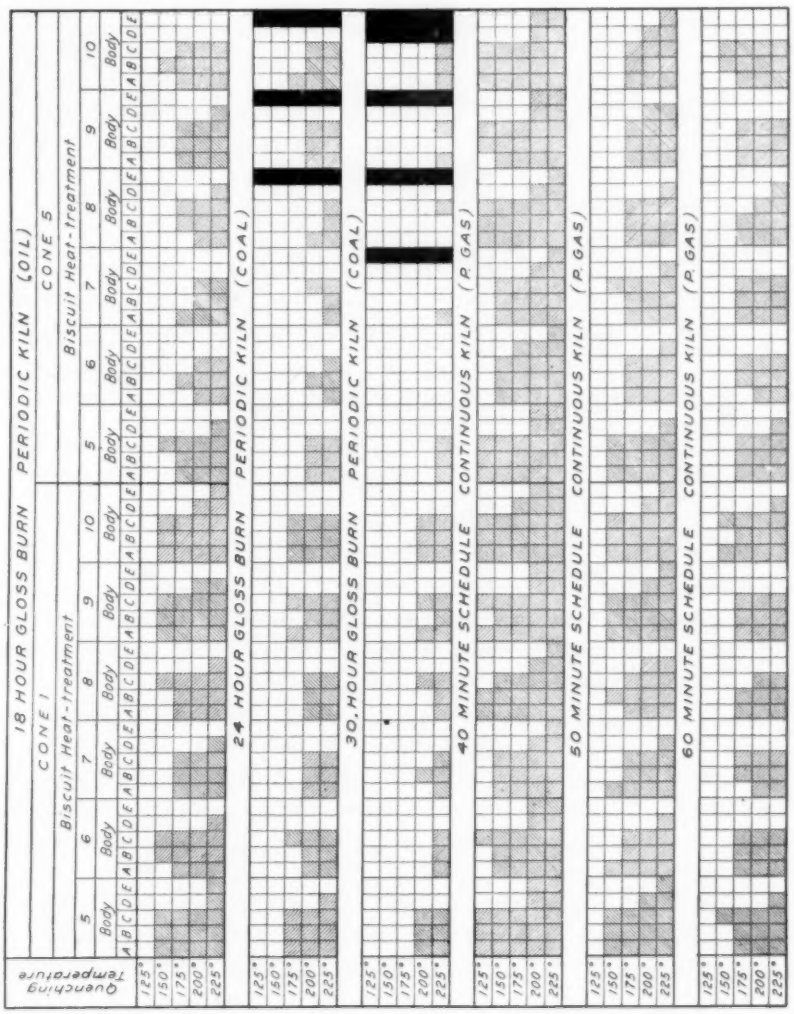

18 HOUR GLOSS BURN PERIODIC KILN (OIL)
CONE 1
CONE 5
Biscuit Heat-treatment
5 6 7 8 9 10
Body
A B C D E
Quenching temperature
125° 150° 175° 200° 225°
24 HOUR GLOSS BURN PERIODIC KILN (COAL)
30 HOUR GLOSS BURN PERIODIC KILN (COAL)
40 MINUTE SCHEDULE CONTINUOUS KILN (P GAS)
50 MINUTE SCHEDULE CONTINUOUS KILN (P GAS)
60 MINUTE SCHEDULE CONTINUOUS KILN (P GAS)
Glaze
Crazed
Shivered

FIG. 2.

A body containing 35.0% of flint and 42.0% of "Hercules" when gloss fired to cone 1 or cone 5 in 17 hours showed no signs of shivering. A 35.0% mixture shivered slightly when gloss fired in 20 hours.

To produce a body free from crazing and shivering we recommend the use of 20.0% of "Hercules" clay when the duration of the gloss burn in a

periodic kiln is less than 18 hours or the schedule of a tunnel kiln is 50 minutes or less. Fifteen per cent of "Hercules" clay should be used when the time of firing a periodic kiln is about 24 hours or the schedule of the tunnel kiln is 60 minutes or more. If the time of firing of the gloss periodic kiln is maintained at about 30 hours the percentage of "Hercules" clay used in the body should not exceed 10.0%

It must be remembered that "Hercules" clay is neither a ball clay nor a china clay, but a cross between these two. It does not have as great a shrinkage as English ball clay, but its shrinkage is more than that of English china clay. "Hercules" clay has a modulus of rupture of 325 pounds per square inch, while our best grade of English ball clays have a transverse strength of about 400 pounds per square inch, and English china clays 20 pounds. The absorption of this clay is less than that of the imported china clays but greater than that of ball clays which vitrify at cone 8 to 9. "Hercules" clay has a fired color far better than the best grade of English ball clay on the market but it is not as white as our best grade of kaolins.

Therefore, it can readily be seen that in order to use this clay to its best advantage it must be substituted for both a portion of the china clay and ball clay in whiteware bodies.

Absorption

The opinion is widely held among potters that the greater the porosity of the body the greater is its tendency to craze. When a potter has trouble from crazing he will invariably increase his biscuit fire, regardless of the cause of the crazing. Often times the ware is fired so hard in the biscuit as to cause a marked increase in the biscuit losses due to an increase in the amount of stuck and warped ware; also the seconds and thirds are increased due to blueware, cut ware, too thin a glaze, or dry edges.

Regardless of the insistence upon the part of nearly every practical potter that there is a direct relation between the porosity of a body and its tendency to craze, it was quite evident from an extensive analysis of factory results that direct relation does not exist. This is borne out by the results in Fig. 2. There can be quite a range in absorption without any appreciable change in crazing behavior, and either an increase or a decrease in absorption beyond certain limits will cause crazing. In other words a body with a low absorption crazes just as quickly as one with a high absorption, all other factors being equal.

Doubtless the average potter formed his opinion regarding the value of increased biscuit fire as a cure for crazing from two different sources. First, it is well known that vitreous china shows very little, if any, tendency to craze. However the practical potter errs when he fails to take into consideration the high flint content (38.0% to 40.0%) of a vitreous china

body as compared with that of an average semi-porcelain body 30.0% to 34.0%. This increased flint is sufficient in itself to cause the difference in crazing behavior rather than the degree of vitrification. Second, in nearly every case when a potter has had trouble from crazing and has increased his biscuit fire, the tendency of his ware to craze has been decreased. But again in drawing his conclusions he fails to consider a very important factor, the thickness of the glaze coating. With increased biscuit fire and the resulting decreased absorption of the ware, there is always a decrease in the thickness of the glaze which is the direct cause of the decreased crazing noted. In other words the same results are obtained by just dipping the ware thinner as can be secured by an increased biscuit fire, at the same time eliminating the many objectionable features caused from a low absorption, such as warpage, blue ware, cut ware, too thin a glaze, etc., which are as sure to follow in the regular process of manufacture semi-porcelain dinner ware, as night follows the day.

The following investigation was made to verify the above results and to more clearly define the permissible range in absorption.

A number of sets of trials, each consisting of twelve five-inch plates, were biscuited in various sections of a biscuit and gloss kiln and in a porcelain kiln fired to cone 11. The absorption of each set of trials was determined and those selected for this test which possessed the desired porosity. All the selected trials were soaked in water; dipped in a glaze weighing 25.5 ounces to the pint; dried; gloss fired to cone 3 in 24 hours; then tested for crazing. The results are given in Table IV.

TABLE IV

No.	Absorption	Quenching temperature				
		125°C	150°C	175°C	200°C	225°C
1	1.5%	..	Crazed	....	....	..
2	3.0	..	Crazed	....	....	..
3	4.9	..	Crazed	....	....	..
4	5.6	..	....	Crazed	....	..
5	6.6	..	....	Crazed	....	..
6	7.5	..	....	....	Crazed	..
7	8.3	..	....	....	Crazed	..
8	9.5	..	....	....	Crazed	..
9	10.5	..	....	....	Crazed	..
10	11.3	..	....	....	Crazed	..
11	12.6	..	....	....	Crazed	..
12	13.4	..	....	Crazed	....	..
13	14.6	..	Crazed	....	....	..
14	15.3	..	Crazed	....	....	..

A mere cursory examination of the results in Table IV, which have been derived from large commercial tests and not mere laboratory tests, should make it very clear to the most conservative potter that only under certain

conditions would it be advisable to increase the biscuit fire to cure crazing. If the absorption of the ware in the first ring is greater than 7.0% and the ware in the third ring has an absorption greater than 13.0%, then and only then would it be best to increase the biscuit fire. If the absorption of the ware in the third ring exceeds 13.0%, but the first ring ware has an absorption of less than 7.0%, it is simply a case of bad heat-distribution, and there is no cause for increasing the biscuit fire if crazing occurs. However, the method of firing should be given prompt attention and the absorption brought within reasonable limits.

Best results are obtained with an approximate absorption of 7.0% to 12.0%. Either a marked decrease below the 7.0% or an increase beyond the 12.0% would cause an increase in the crazing behavior of the average semi-porcelain body, all other factors being equal.

This gives a permissible variation in absorption of about 5.0% which is ample for good firing conditions in periodic kilns, and can be maintained over long periods of time provided proper methods of control are used.

Time-Temperature of Gloss Burn

Seger and other writers have emphasized the value of increasing the temperatures of the gloss fire as an effective means of curing crazing. However, nearly every semi-porcelain manufacturer regularly fires his ware from cone 1 to cone 4, and oftentimes the ware in the first ring reaches cone 5. This is practically the limit of gloss heat-treatment with the type of bodies that are used today, as any increase beyond cone 5 would cause considerable warpage of the ware in the first ring. Again we see that commercial conditions of manufacture practically eliminate another suggested cure for crazing.

By comparing the crazing behavior of the trials gloss fired to cone 1 with those gloss fired to cone 5 (Fig. 2), we note that in the case of the three periodic kiln burns the plates show a marked decrease in their tendency to craze when fired to the higher temperature but that there was very little difference, if any, between the cone 1 and cone 5 heat-treatment in the three tunnel kiln burns. Why this difference between periodic kiln and tunnel kiln? It is evident that some other factor besides temperature is the direct cause of the decreased crazing when the temperature of the gloss fire in a periodic kiln is raised. The only factor that could enter into the problem would be the time factor. When one analyzes the manner in which the heat is advanced in periodic and tunnel kilns, it becomes very plain that there is a vast difference in the time. In the periodic kiln the time required to go from about cone 05 where the glaze starts to mature to cone 5, is much greater than the time between cone 05 and cone 1. But on the other hand the conditions in the tunnel kiln are vastly different. Here the moving cars are moved through the hot zone at the same rate with the

top at about cone 5 and the bottom at cone 1, the ware on the top of the car being fired to cone 5 in approximately the same maturing time as the ware on the bottom of the car is fired to cone 1.

This brings us to the consideration of one of the most important factors affecting crazing: the *time factor*, or the length of the gloss burn; but one that has very seldom, if ever, been considered to any great extent by the practical potter.

The effect of time on crazing is very plainly shown by the data in Fig. 2 From a study of these results it becomes perfectly evident that by increasing the time of firing a gloss kiln by six hours or more, within the practical limits of 18 to 30 hours, a very decided decrease in crazing occurs. The fact is irrefutable that in the time factor the potter has a very good means of decreasing crazing.

There is no assumption in saying that upon the occurrence of crazing, the first and best thing to do is to increase the time of firing the gloss kiln, if less than 30 hours. Such a procedure is by far the most logical thing to do regardless of the direct cause of the crazing, because it supplies an immediate remedy, so necessary in a pottery, if large losses are to be avoided. It produces a temporary relief without decreasing the output to any marked degree, or causing other losses such as warpage, dry edges, etc. It does not interfere with the orderly processes of manufacture, and affords the manufacturer ample time to investigate the direct cause of the trouble.

It must be borne in mind that when the length of the gloss burn is increased the extra time should be consumed chiefly in the latter portion of the burn, as is the general practice. It is possible to increase the time of firing a periodic gloss kiln without decreasing the crazing, by using all the extra time during the fore part of the burn. In other words it is the maturing time of the glaze (cone 05 up) that must be increased if crazing is to be decreased by increasing the length of the gloss burn.

The use of oil as a fuel in gloss kilns together with a decrease in firing time; the tunnel kiln with its short hot zone; and the general demand for more speed in manufacture, have been the paramount causes of the continued crazing of American dinner ware.

There is no doubt but that fuel oil firing of periodic gloss kilns, and the tunnel kilns, regardless of the short maturing time allowed the glaze, have many advantages which are meeting with favor among the potters. Therefore, in order to meet these new conditions and the demand for speed, it becomes necessary to make changes in the body composition. The only change that we have found which would meet all the practical conditions of manufacture and at the same time decrease the tendency to craze, is the substitution of "Hercules" clay for a portion of the English ball and English china clay in the regular semi-porcelain body. A "Hercules"

clay body is not only free from crazing but it has a much greater strength in the clay state with the resulting decreased biscuit losses.[1]

Acknowledgment.—The writer wishes to acknowledge his indebtedness to C. L. Sebring, President, Sebring Pottery Co., for many timely suggestions and assistance throughout the entire investigation. It was only Mr. Sebring's progressive principles that made it possible to bring this investigation to its successful conclusion.

We also wish to express our appreciation of the assistance of Donald Allbright, Asst. Manager, Limoges China Co.: Harry McMasters, Gen. Supt., Sebring Pottery Co.; and Raymond Green, Supt., Gem Clay Forming Co.

Sebring Pottery Company
Sebring, Ohio

[1] *Jour. Amer. Ceram. Soc.*, **5** [9], 588 (1922).

DEFORMATION STUDIES OF SILICATES AND ALUMINUM SILICATES OF THE ALKALIES

By Bryan A. Rice[1]

ABSTRACT

The following investigation includes studies of the two ternary systems K_2O-Al_2O_3-SiO_2 and Na_2O-Al_2O_3-SiO_2.

In each system two areas of low fusibility were found; one including members high in alkali, low in silica, and low in alumina; the other including those high in silica, low in alkali, and low in alumina. In both systems the high silica area was the one studied in detail as being of more practical ceramic value.

On each triaxial three eutectics (two binary and one ternary) were established. They had the following compositions:

Per cent	Molecular	Appr. def.
K_2O - Al_2O_3 - SiO_2	K_2O - Al_2O_3 - SiO_2	°C
55.0 .... 45.0	1.00 .... 1.291	780
17.5 .... 82.5	1.00 .... 7.43	880
17.4 - 5.2 - 77.4	1.00 - 0.276 - 6.978	870
Na_2O - Al_2O_3 - SiO_2	Na_2O - Al_2O_3 - SiO_2	
51.5 .... 48.5	1.00 .... 0.972	830
18.4 .... 81.6	1.00 .... 4.579	860
17.5 - 5.4 - 77.1	1.00 - 0.185 - 4.55	800

The terms "eutectic" and "deformation eutectic" are used in this paper to designate those compositions which require the lowest temperature to complete deformation when uniformly heated with other compositions in the manner outlined in the following studies. Deformation was judged by the same method used with standard pyrometric cones.

Introduction

The Geophysical Laboratory, Carnegie Institute of Washington, Washington, D. C., has done some very careful and accurate work on the following ternary systems:

CaO-Al_2O_3-SiO_2	(*Jour. Amer. Chem. Soc.*, **38,** 568 (1916)).
MgO-Al_2O_3-SiO_2	(*Am. J. Sci.*, **45,** 301 (1918)).
CaO-Al_2O_3-MgO	(*Jour. Amer. Chem. Soc.*, **6** (1916)).
CaO-SiO_2-MgO	(*Am. J. Sci.*, **46,** 48–81 (1919)).

A. S. Watts[2] has published results on MgO-Al_2O_3-SiO_2 system, and also the ternary system BaO-Al_2O_3-SiO_2. However, to the best of the writer's knowledge, no data is available dealing with the thermal behavior of K_2O and Na_2O as oxides in combination with SiO_2 or Al_2O_3 and SiO_2. Some data on the straight line K_2O-SiO_2 is available in "Ternary System H_2O-K_2SiO_3-SiO_2."[3] C. J. Peddle in his article "The Development of Various Types

[1] Presented as a thesis for the Degree of Master of Science at Ohio State University. Received Nov. 28, 1922.

[2] *Trans. Amer. Ceram. Soc.*, **19,** 457 (1917).

[3] Morey and Fenner, *Jour. Amer. Chem. Soc.*, **39** [6], 1173 (1917).

of Glass,"[1] includes K_2O-SiO_2 and Na_2O-SiO_2 glasses but his study is confined almost totally to solubilities and refractive indices and very little is said regarding temperature. Therefore the following investigation of the silicates and aluminum silicates of the alkalies was undertaken in an attempt to provide the ceramist with data which would prove of value in analysis or synthesis of glasses, glazes and enamels.

The method of study was to make up cones of varying composition and observe their deformation behavior when heated. Where possible, the actual raw materials were used, it being thought advisable to study them in this form and later, if time permitted, to fuse each member, pulverize, make into cones, and take deformation observations on these fritted mixtures. Commercial raw materials were used rather than chemically pure because we were after practical results which could be applied commercially.

The same general rate of heating was maintained as nearly as possible for each burn. It was found by trial that as much as one or even two hours difference in total time of heating did not affect their order of deformation although the final temperature might vary. Observation was confined to order of deformation in establishing the eutectic and, although temperatures were recorded for each burn, it was not considered vital to attempt to measure accurately the temperature of deformation of the eutectic. At all times great care was taken to insure uniform heat throughout the furnace.

It is realized that to really complete the work started, data other than that of deformation should be secured such as solubility studies, refractive indices, degree of reaction of one constituent with another, and possible mineral formations which might take place. It is hoped that it will be possible to make such determinations in the future investigations of which this is merely the beginning.

All members on any of the triaxials shown in the following studies are given in per cent by weight.

Series I. K_2O-Al_2O_3-SiO_2

For this purpose it was desired to use as far as possible the simple oxides. Al_2O_3 and SiO_2 were easily procurable in that state. However, it was necessary to add K_2O as a simple salt. K_2CO_3 and KNO_3 are commercial methods of accomplishing this.

It was decided to use K_2CO_3. On attempting to make up cones from the raw materials, difficulty was encountered in using this material owing to its extreme deliquescence when pulverized. The batch could be mixed up to the proper consistency but, before cones could be made, it would set so hard that it could not be worked.

[1] *Jour. Soc. Glass Tech.*, **4**, 1–107 (1921)

This fact caused us to change to KNO_3 which was much better. Using dextrin as a binder, the cones were made up in the standard size and shape of Orton's pyrometric cones.

First Burn (Series I).[1]—Referring to the article by Morey and Fenner on "The Ternary System H_2O-K_2SiO_3-SiO_2,"[2] it was decided that some of the cones would go down at a temperature below red heat. This would necessitate some outside source of light. For this purpose a small electric furnace was used. A platinum-platinum rhodium thermocouple was inserted in the back of the furnace. The front of the furnace was built

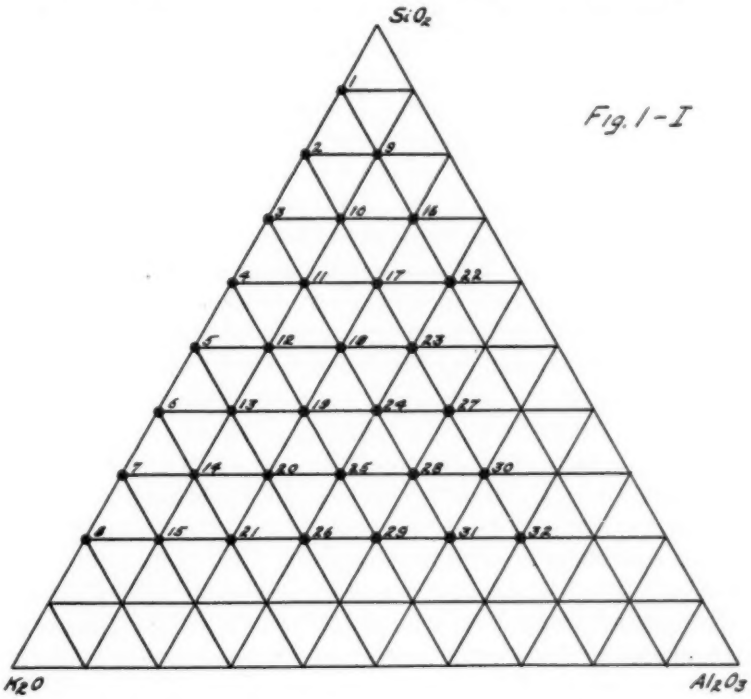


Fig. 1-I

up so that an electric light outside would illuminate the cones and they could be observed through a small peep hole also in the front.

The first burn consisted of members 1 to 8 on the straight line series between K_2O and SiO_2. (Fig. 1-I.) The cones were placed in the furnace and heated slowly requiring $8\frac{1}{2}$ hours to heat from room temperature to 670°C. At this temperature all cones were down but 1, 2, 3 and 4. These showed no signs of deformation, except the very tip of 4. The remaining cones had not deformed in the regular way but seemed to fall apart or slump down.

[1] October 22, 1919.

[2] *Loc. cit.*

In fact there was much doubt whether there was any action between the KNO_3 and SiO_2 at all. It seemed more probable that the KNO_3 burned out leaving the SiO_2 behind in its original state. If true, those cones containing a large quantity of KNO_3 did not have sufficient SiO_2 left to hold its shape and simply crumbled down while those higher in SiO_2 maintained original positions. Cone 5, which was a 50–50 mixture, seemed to do a little of both.

At any rate it seemed evident that either of two things happens:

1. KNO_3 volatilizes before it can act on SiO_2.
2. Rate of heating is too fast to allow action to take place.

Another burn was made heating up at a slower rate.

Second Burn—(**Series I**).—For this burn cones 3, 4, and complete triaxial 5-8-26 (Fig. 1-I) were used. This included all members which had gone down in Burn 1. The temperature was raised more quickly in this burn requiring only 8 hours to reach 1100°C.

Again 3 and 4 did not go down. The remaining cones behaved in the same manner as those which deformed in Burn No. 1.

Upon observing cones 1, 2, 3 and 4 of this burn and also the previous one, it was noted that they had a porous structure when taken from furnace. This porosity increased with increasing KNO_3 in original cone mix. This serves to strengthen the theory that volatilization took place too quickly for the KNO_3 and SiO_2 to react.

Third Burn—(**Series I**).—The method of burning was changed as follows. The furnace was brought to 1050°C and held at this temperature while the cones were placed in the furnace and then order of deformation noted. All members in Fig. 1-I were used.

All cones went down under this treatment. The reaction was very rapid and violent. The higher SiO_2 members showed a more nearly normal deformation but all cones were bloated and bubbly. The extreme rapidity of reaction indicated that this temperature was too high for results that could be graded and classified.

Fourth Burn—(**Series I**).—This was conducted the same as Burn No. 3, but the furnace temperature was 850°C. Several cones, high in Al_2O_3 and SiO_2, did not deform.

In the various cones which remained standing the same condition was observed as in the Burns 1 and 2 in which the temperature was gradually raised. The condition to which it referred was attributed to volatilization. Subsequent examination with the aid of the microscope showed that it was more probable that the KNO_3, owing to its extremely low melting point, flowed away without reacting with the SiO_2 and Al_2O_3 leaving these behind in their natural state. The cone plaques in which they were placed showed evidence of absorbing this extremely fluid KNO_3.

Smelting Members.—From the foregoing it was evident that the melting point of KNO_3 (337 °C) was entirely too low to give results with cones made up from the raw materials. Hence it was decided to try smelting the batch and then make up cones from the resultant frit.

A batch totaling 100 grams of member No. 8 was placed in a large porcelain crucible. This was heated in a furnace, the source of heat being a Meeker blast burner. With this quite a high temperature could be obtained.

Here again trouble was encountered. The KNO_3 would melt down rapidly but was extremely slow in taking SiO_2 into solution. Through the liquid KNO_3 was a honey comb mass which seemed to melt with great difficulty and was too viscous to remove from the crucible. Also, temperature control to prevent frothing over was difficult.

After several trials with no better results even at high temperatures, K_2CO_3 was substituted for the KNO_3. This seemed to work much better. The probable reasons were its more alkaline nature and its higher melting point (909 °C) which approaches that of K_2SiO_3.

The first trial produced a clear, highly deliquescent glass. The sample was marked 8-A. There was considerable irregularity connected with this trial. It was allowed to heat too long and had practically eaten through the crucible. The fact that it probably dissolved considerable SiO_2 and some Al_2O_3 in so doing seems to account for its clearness. Under the microscope it showed all glass. Analysis showed 32.26% SiO_2 and 7.5% Al_2O_3.

The next trial, marked 8-B, was more closely watched and the moment a clear solution was obtained the melt was poured. The method of chilling in all cases was to pour into water-jacketed pan. Analysis showed: 24.84% SiO_2; 4.26% Al_2O_3.

It was then attempted to prepare some K_2SiO_3 in order to study its properties under the microscope. For this purpose a platinum dish with a porcelain cover was substituted for the porcelain crucible. A mixture of K_2CO_3 and flint (both commercial) totaling 43 grams raw mix and proportioned to give theoretical K_2SiO_3, was placed in the dish and heated till a clear quiet fusion was obtained. This was chilled as above.

That portion of the melt next to the pan which cooled quickly resulted in a transparent glass with a slight greenish tint while that which cooled more slowly crystallized forming a cloudy white mass. Under a magnifying lens rather large fibrous crystals could be seen. Under the microscope the crystallized portion showed fibrous crystals, probably orthorhombic, with parallel extinction. Index of refraction was about 1.51 to 1.52 approximately the same as the glass. Interference figure showed emergence of an acute negative bisectrix. When a drop of water was placed upon the crystals under the microscope they did not dissolve uniformly but broke

up into shred-like forms probably along cleavage planes. From Fenner's description (the ternary system H_2O-K_2SiO_3-SiO_2) these crystals were identified as the disilicate $K_2O.2SiO_2$.

A second melt showed the same results as the first.

This would indicate quite a bit of volatilization of K_2O.

From the above it seemed advisable to smelt the members in a platinum dish to prevent contamination from dissolved SiO_2 and Al_2O_3 and afterwards to analyze the melts to obtain the proper positions on the triaxial diagram.

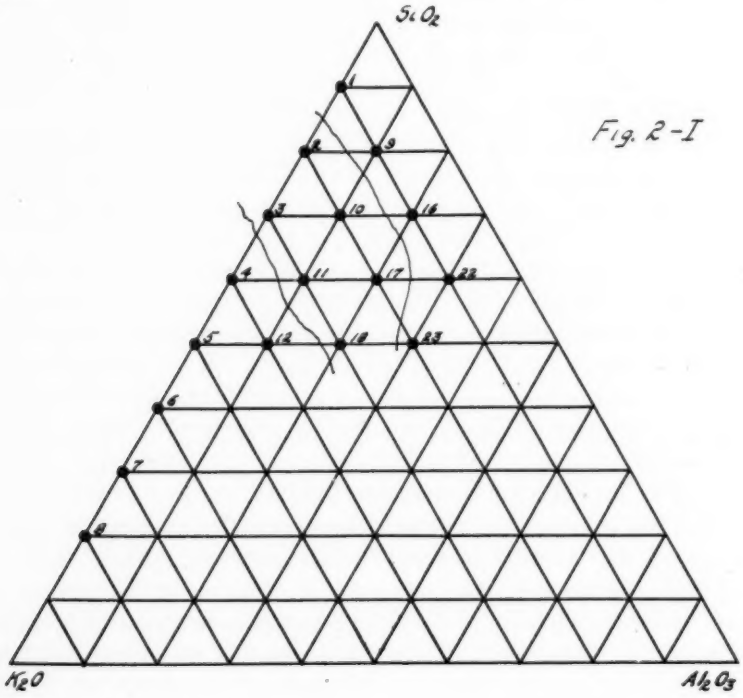


Fig. 2-I

Members 5, 6, 7 and 8 smelted with comparative ease but those with increased SiO_2 content above that of 5 required an almost prohibitive temperature. Member 4 was smelted at the full temperature of the Meeker blast lamp before a fusion was obtained, while those higher in SiO_2 were not obtained in fused state. The addition of Al_2O_3, even to those high in K_2O, produced a fusion too viscous to pour from the platinum dish.

The above difficulties seemed to make it less trouble to make up cones from raw materials using K_2CO_3. A preliminary burn in a small electric furnace on the high K_2O members was made to see if a regular deformation would take place instead of results as obtained with cones made from KNO_3. This burn showed a quite uniform deformation.

Consequently it was decided to use K_2CO_3, the analysis of which was 57.4% K_2O. Results from the Na_2O-Al_2O_3-SiO_2 series which was started using Na_2CO_3 showed it impractical for our purpose to investigate the high K_2O area. This will be discussed later. However, for the first burn we did include some high K_2O members on the straight line K_2O-SiO_2. (Fig. 2–I.)

Fifth Burn—(Series I).—Started 3:45 P. M.[1]

Time	M. V.	Temp. °C	Remarks
4:15	7.6	495	
4:20	8.75	585	
4:30	9.5	660	
4:45	10.4	720	6, 5, 7 and 2 started
4:50	10.6	740	8 started
4:52	11.0	770	12 tipped backwards slightly
4:55	11.25	795	7, 6 and 8 down—4 started
5:00	11.4	805	2 down
5:20	12.0	860	
5:25	12.5	900	3 down—10 and 11 started
5:30	12.6	905	11 down followed by 10
5:33	12.6	905	Heat turned off

Starting order.....	6	5–7	2	8	4	3	11	10	9
Final deformation.....	7	6	8	2	3	11	10		

7, 6 and 8 were very fusible and, due to excessive alkali content, were almost totally absorbed by the cone plaque. They seemed to be merely K_2SiO_3 + K_2CO_3 and took up moisture from the air to such an extent as to make them soft and gummy like water glass. They did not have the stony, slag-like appearance such as was noted in the Na_2CO_3 series but were rather clear fusions. While realizing the importance of further study in this field before the ternary system K_2O-Al_2O_3-SiO_2 could be considered complete, it did not seem practical to spend time to do so at present, because their extreme solubility would seem to unfit them for any valuable use in enamels. Hence, completion of study of this area was deferred and the upper area of low fusibility was considered in the work immediately following. However, there seems to be a straight line eutectic between members 6 and 7 which, when corrected according to analysis of K_2CO_3 will have composition 55% K_2O and 45% SiO_2 or in molecular formula, K_2O-1.291, SiO_2 at 780°C. Geophysical Laboratories found a eutectic at K_2O-1.35, SiO_2 (775°C).[2]

Member No. 2 started first and final deformation was reached first of the cones in this upper area. No. 3, while starting later, deformed very quickly and developed extremely low viscosity. From this standpoint,

[1] March 24, 1920.

[2] Morey & Fenner, H_2O-K_2SiO_4-SiO_2, *loc. cit.*

it was easily the most fusible member in the area. Of the cones which reached final deformation No. 11 was next, followed by No. 10.

There seemed to be quite a range in time and temperature between the final deformation of No. 2 and final deformation or even starting of 3, 10 and 11.

Upon standing for a while, all cones except 1, 2, 9, 16 and 22 showed a surface coating probably due to absorption of moisture from the air which brought the soluble salts to the surface where they crystallized. A very slight trace was noticed on No. 2. This was explained as due to the fact

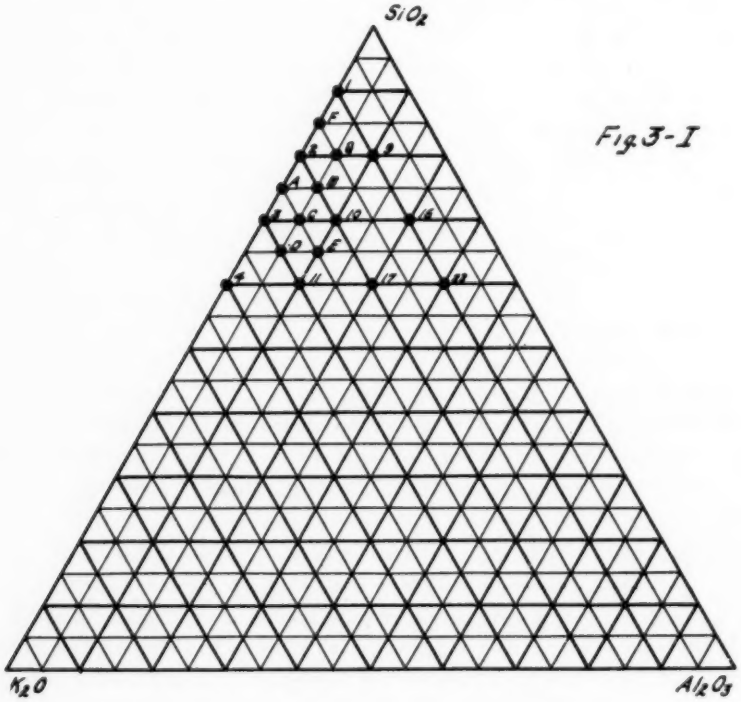


Fig. 3-I

that No. 2 is very close to the eutectic and a state of equilibrium was reached. Those members higher in K_2O would have an excess of K_2O over and above the eutectic mixture which would allow the above described solution and subsequent crystallization. Those members higher in SiO_2 and Al_2O_3 would use up all the K_2O in the eutectic mixture and the excess would be insoluble SiO_2 and Al_2O_3.

Sixth Burn (Series I).—This included only members 2, 10, 17, 3, 11 and 18 (Fig. 2-I) which included the softer members from Burn No. 5. Started 2:30 P. M.

Time	M. V.	Temp. °C	Remarks
3:30	7.5	480	
3:45	9.1	620	
4:05	10.2	705	
4:30	11.6	820	
4:40	12.0	855	2 started
4:50	12.4	890	3 started
4:55	12.5	900	2 down
5:10	13.0	940	11 started
5:15	13.1	945	
5:20	13.25	955	3 down—10 started—11 down
5:35	13.6	985	
5:55	14.0	1020	10 down. Temperature practically constant for last 5 minutes—current shut off.

Starting.....	2	11	3	10
Down.....	2	3	11	10

This was a very good check. The relative behavior of the cones was much the same, particularly was this true of 2 and 3. This establishes No. 2 as the eutectic (deformation) of this area within 10% limits. No. 3 again showed decidedly the least viscosity after the cone once started.

Seventh Burn (Series I).—In this burn the limits were brought down to 5%, members 2, A, 3, B, C, D, 10, E and 11 being used. (Fig. 3-I). Started 9:15 A. M.

Time	M. V.	Temp. °C	Remarks
11:00	8.0	520	
11:35	10.5	730	
12:00	11.8	840	2 and B started
12:05	12.0	855	
12:10	12.2	870	A started—B down
12:13	12.3	880	A tipped over and is touching tip of 2. They are going down together
12:15	12.4	890	2 and A down
12:20	12.5	900	D started—E tipped backwards
12:25	12.6	905	D down
12:31	12.85	920	C started
12:35	12.95	935	C down
12:38	12.97	940	3 started
12:40	13.15	950	3 down—E down backwards

Removed from furnace—replaced in furnace 12 M. V. and temperature brought back up to 13.2 to see effect on viscosity. Removed from furnace again.

Started.....	2	B	A	D	E	C	3
Down.....	B	2-A	D	C	3-E		

Eighth Burn (Series I).—This burn was principally a check on No. 7. Members F and G were added and 10, E and 11 dropped as these last showed no signs of deformation in Burn No. 7. (Fig. 3-I.) Started 10:00 A. M.

Time	M. V.	Temp. °C	Remarks—Using Bureau of Mines thermocouple
11:30	5.5	640	
12:15	7.4	820	
12:30	7.7	845	B started
12:35	7.8	855	C started
12:40	8.0	870	2 started
12:44	8.1	880	B down first followed by 2
12:47	8.2–	890	C down
12:53	8.4	910	A started
12:57	8.5	915	A down—3 and G started
1:00	8.55	920	3 down
1:07	8.65	930	
1:10	8.75	940	D down

Started..... B C 2 A 3 G D
Down..... B 2 C A 3 D

The manner in which B deformed indicated that it was farther ahead of 2 than the data shows as far as deformation is concerned. In this burn 2 showed slightly less viscosity than A. C went down sooner than previously

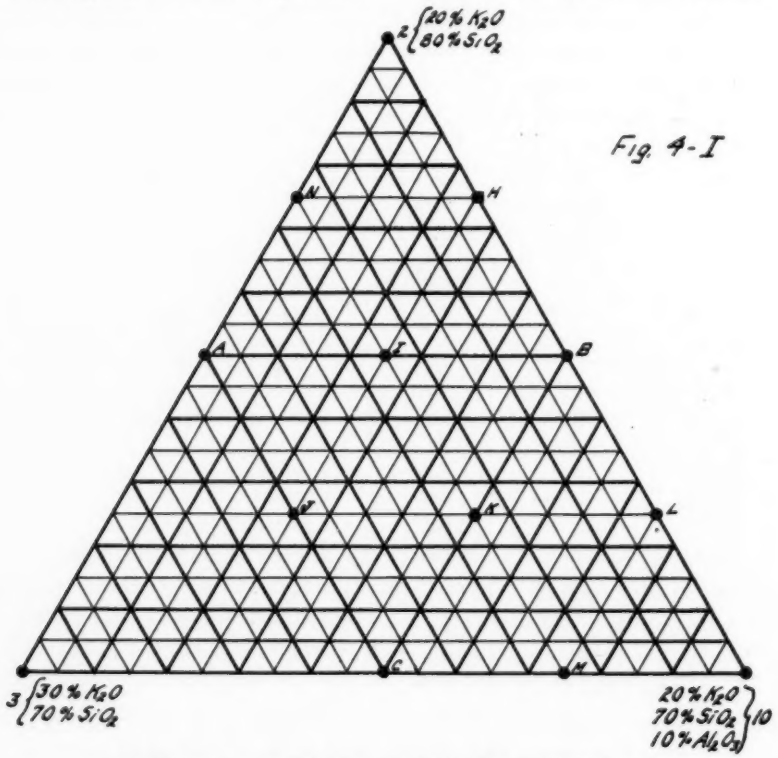


Fig. 4-I

B—Eutectic—20.00% K_2O—5.00% Al_2O_3—75.00% SiO_2.
B—Corrected—17.41% K_2O—5.16% Al_2O_3—77.43% SiO_2.
B—Molecular Formula—K_2O—0.276 Al_2O_3—6.978 SiO_2.

but more nearly in the order one would expect. Considering B as nearer the deformation eutectic than any of the rest, the order of deformation was practically what would be expected with the possible exception that the position of 3 and D should be reversed.

As noted, G started to deform but did not proceed very far. No evidence of deformation of F was observed.

B can be considered as the deformation eutectic within limits of 5%.

Member 2 is a deformation eutectic between K_2O and SiO_2 within 5% limits. Its composition as corrected from analysis of the K_2CO_3 used is 17.5% K_2O-82.5% SiO_2 (molecular formula K_2O-7.43 SiO_2), 880°C. This does not check the figures from Geophysical Laboratories which were, in molecular formula K_2O-4.0 SiO_2, 525°C.

Ninth Burn (Series I). (2.5% limits).—Limits were brought down to 2.5%. Members 2, H, B, L, I, C and K were used. (Fig. 4-I.) Started 1:30 P. M.

Time	M. V.	Temp.°C	Remarks
2:15	7.5	480	
2:45	9.8	670	
3:15	11.4	805	
3:25	11.6	820	2 started
3:30	12.0	855	
3:35	12.2	870	2 down—C started
3:45	12.4	890	C down—K started
3:42	12.5	900	H started
3:53	12.6	905	K down—I and B started
3:56	12.65	910	H down—I down—B down
4:00	12.75	915	Heat shut off.

This burn did not check previous results in that 2 was down ahead of B while in both Burn No. 7 and Burn No. 8 the positions were reversed.

Tenth Burn (Series I).—Check on Burn No. 9. Started 8:30 A. M.

Time	M. V.	Temp.°C	Remarks
9:25	8.2	540	
9:50	9.8	670	
10:00	10.5	730	
10:15	11.2	790	
10:25	11.55	810	2 started
10:35	11.8	840	2 down
10:37	11.95	850	C started
10:50	12.3	880	C down—K, B and I started
10:52	12.4	890	H started—K down
10:55	12.6	905	H down—I down

In this one also 2 was down ahead of B.

To attempt to check this inconsistency cones of 2 and B, made up at different times, were mounted. There were 3 of each and were marked 2. — 2.. — 2... and B. — B.. — B...

Eleventh Burn (Series I).—Started 8:30 A. M.

Time	M. V.	Temp. °C	Remarks
9:50	8.0	530	
10:15	9.85	680	Tip of 2.. started backwards 2... started
10:43	11.2	790	B... started
10:49	11.4	805	B... down—B. started 2. started backwards
10:58	11.6	820	2... started—2.. started forward B.. started
11:04	12.0	855	2.. down
11:15	12.3	880	
11:22	12.5	900	B. down—B. . down
11:30	12.8	920	2. down

B... was down ahead of 2... B. was down ahead of 2., but 2.. was down ahead of B.. — 2.. and B.. were from the same lot as gave the inconsistent results in Burns No. 9 and No. 10.

Twelfth Burn (Series I).—This was made as a check on 2 . . . and B . . . introducing member H also. Started 2:15 P. M.

Time	M. V.	Temp. °C	Remarks
3:10	7.8	510	
3:45	10.4	725	
3:55	11.0	770	
4:15	12.0	855	B started
4:23	12.2	870	2 started
4:27	12.3	880	
4:30	12.4	890	B down
4:33	12.5	900	2 down—H not started
4:50	13.0	935	H started

Thirteenth Burn (Series I).—As a final check new cones were made of 2, B and H. Started 9:05 A. M.

Time	M. V.	Temp. °C	Remarks
10:40	9.4	640	
10:50	10.0	690	
11:03	10.8	760	B started
11:15	11.25	790	
11:35	12.2	870	B down—2 and H started
11:38	12.3	880	2 down—H started
11:39	12.3	880	H down

B again was ahead of 2 and H was last.

This seems to establish B as the deformation eutectic within limits of 2.5%, but as in the Na_2O-Al_2O_3-SiO_2 series it must be realized that the deformation points of these last few members lie very close together.

The composition of B from the triaxial is 20% K_2O, 5% Al_2O_3, 75% SiO_2. However, analysis of the K_2CO_3 used showed 17.41% K_2O, 5.16% Al_2O_3, 77.43% SiO_2 or molecular formula K_2O-0.276, Al_2O_3-6.978, SiO_2 (870°C).

Conclusions

1. The members toward the high K_2O end of the triaxial were very deliquescent starting somewhere between members 5 and 6. They became very soft and gummy on standing a short time.

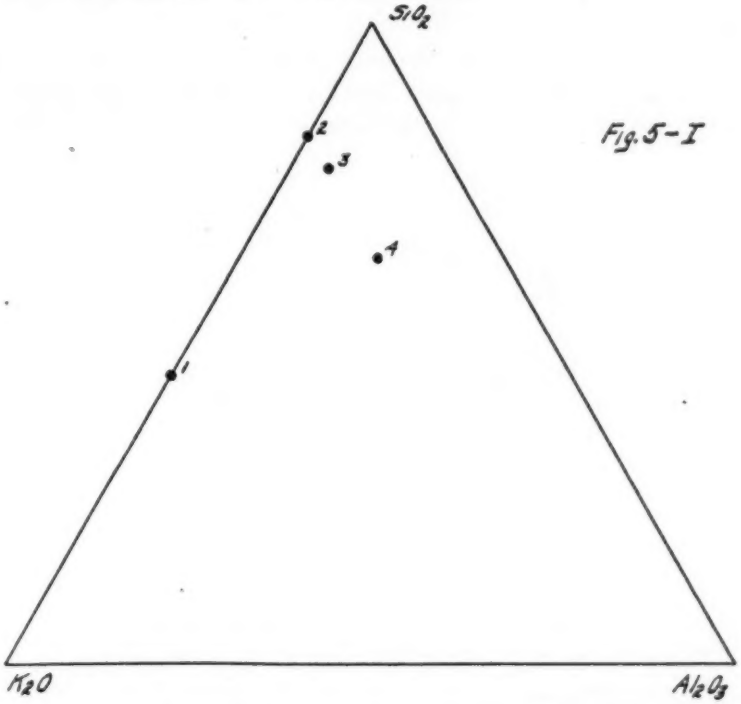


Fig. 5-I

		Limits	Composition							Appr. def., °C
			Per cent				Molecular			
			K_2O	Al_2O_3	SiO_2		K_2O	Al_2O_3	SiO_2	
1	Binary Eutectic	10%	55.0	..	45.0		1.00	..	1.291	780
2	" "	5%	17.5	..	82.5		1.00	..	7.43	880
3	Ternary "	2½%	17.41	5.16	77.43		1.00	0.276	6.978	870
4	Pure Potash Spar		16.90	18.36	64.74		1.00	1.00	6.00	1350

2. Two deformation eutectics were noted on the straight line between K_2O and SiO_2.

(*a*) 55% K_2O
45 SiO_2
(780°C)

(*b*) 17.5% K_2O
82.5 SiO_2
(870°C)

3. A ternary deformation eutectic was found of the composition:

17.41% K_2O
5.16 Al_2O_3
77.43 SiO_2

4. This ternary eutectic has a much higher SiO_2 content and lower Al_2O_3 content that any natural potassium aluminum silicate mineral known.

5. Deformation temperature is low (870°C) which brings it close to that of a glass or enamel.

Series II. Na_2O-Al_2O_3-SiO_2

This series was started while work on the K_2O-Al_2O_3-SiO_2 series seemed to indicate the necessity for using the carbonate rather than the nitrate. Sodium carbonate analyzing 42.9% Na_2O was used.

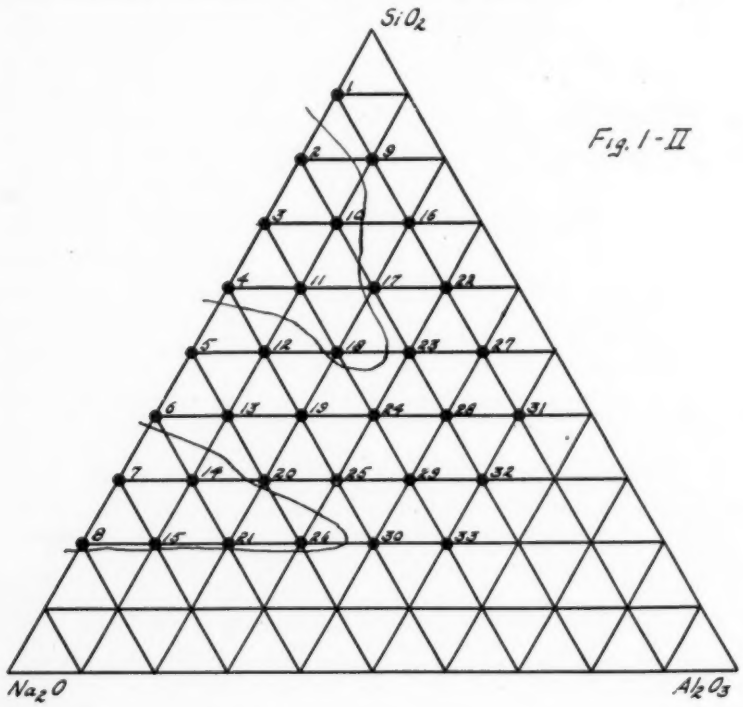


Fig. 1-II

First Burn (Series II).—A series of cones (Fig. 1-II) were then made for the purpose of burning the complete set in one of the large gas fired kilns. A muffle large enough to hold this series was built in the kiln in order to insure oxidizing conditions. Since deformation areas, rather than temperatures, were sought, exact temperature measurements were not made, the order and rate of deformation being more desirable.

A base metal thermocouple was used. Also some Orton pyrometric cones were placed in the muffle. From the start of the burn it was seen that the muffle would not heat evenly. The top and the back were the hottest. They showed a bright red, almost yellow heat, while the remainder of the muffle was slightly hotter than the bottom or right side. Con-

sequently the results obtained were not exact. Some interesting observations may be made on some of the cones which were in the same heat zone. Tabular data was as follows:

Time	Milli-Volts	Remarks
8:30	8.4	
8:45	12.5	
9:00	15.0	
9:15	17.2	
9:45	20.5	
10:00	22.5	
10:30	24.8	
11:00	26.2	020 started
11:15	28.2	
11:30	29.3	020 down—2, 3 and 6 started
11:45	29.9	13, 8 and 15 started
11:50	30.2	17 started
12:00	30.5	19 started
12:10	31.2	7, 14 and 11 started
12:15	31.8	20, 21 started—8 broken
		11 tipped against muffle wall
12:25	..	18 started—3 down
12:30	32.3	10 started—2 down—11 down (?)
12:35	..	29 and 31 started
12:40	..	24 and 12 started
12:45	33.0	4 started
1:00	33.9	10 down
1:03	..	15 down—4 broken
1:10	..	23, 28 and 30 started—7 down
1:15	34.5	18 down
1:30	35.0	12 probably down—4 down
		015 had started

That the results obtained may be studied to better advantage, it is better to group them as follows:

Order started	Order down
2–3–6	..
8–15	3
17	2
7–4–11	11?
20–21	10
18	7
10	18
24	4
12	12
4	..

Members 13–19–29–31–23–28–30 which are listed in the preceding data as having started were found to have merely deformed, some through shrinkage when cones were studied after being withdrawn from the kiln. At this

time also it was discovered that No. 26 had started to deform but was not observed in the kiln due to the fact that it had broken. As noted before, when No. 11 started to deform it tipped over and touched the wall of the muffle, thus making the order in which it finally went down a matter of doubt. Study of the cones after withdrawing from the kiln indicated that this member was the most fusible and probably would have been the first to go down had it not been retarded by touching the wall.

While this burn was rather unsatisfactory due to the uneven heat distribution through the muffle, the fact that the majority of the data secured is confined to those cones which were comparatively close together in the high heat zone where the temperature variation was not great makes it worth recording. Therefore, for this burn we will consider only the upper part of the triaxial diagram since those members comprising the lower portion were in the part of the muffle where heat distribution was the poorest.

On the straight line series between soda and silica, members 2–3–4 were the ones which deformed. Of these three, No. 3 was the most fusible. Away from the straight line into the field which also includes alumina we find No. 11 the most fusible followed by 10, 18, 12, 17 and 24 in the order given. The last two members showed only a slight deformation.

To overcome the objections in the above method of heating and to secure more reliable data, this burn was repeated in the electric furnace.

Second Burn (Series II).—The large cones were cut down to a smaller size about $1^1/_2$ inches in length in order to allow them to be mounted in a more compact manner so that they could be placed in the electric furnace and more uniform heat conditions assured.

RESULTS

Cone 020 was down before 7 M. V. was reached.

9.0 M. V.	610°C	8 started
10.25	710	7, 14 and 15 started
11.6	820	2 and 3 also 4, 11 and 015 started
12.0	855	015 down. 8 probably down but hard to see. 21 and 10 started
12.4	885	11, 15 and 3 down
12.5	895	4 and 7 down. 10 either down or broken
12.6	905	21 down

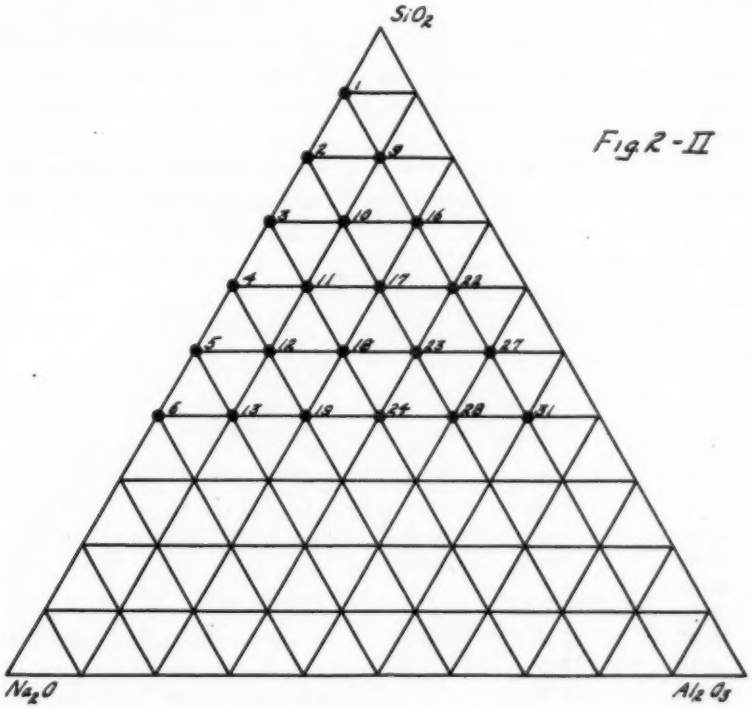
These results show that two areas of low fusibility exist as shown on the triaxial. The members in the area of the high silica content show a glassy condition while those in the lower area where the soda content is highest show more of a slagging condition. Here again member No. 11 seems to show evidence of greatest fusibility; No. 5 is evidently the high point between the two areas. It was hard to observe the order of deformation

due to so many cones being so closely crowded together. The heat distribution was remarkably good.

The preceding burns, while giving no exact data, have shown two things.

First: Two areas of low fusibility exist. Second: One area high in Na_2O does not fuse to a glass but has a stony, slag-like appearance while the area higher in SiO_2 has glassy fusions.

These results were taken as sufficient reason to discontinue further investigation of the high Na_2O field at present and confine our attention to the high SiO_2 area of fusibility.



Third Burn (Series II).—The burning was done in the electric muffle furnace which insured even heat distribution. New cones were made. All members of Fig. 2-II were used. Started 9:30.

Time	M. V.	Temp. °C	Remarks
11:00	8.5	570	
11:20	10.0	690	6 started
11:30	10.8	780	11 started
11:35	11.1	790	13 and 2 started
11:40	11.2	795	24 started
11:42	11.3	800	*2 down.* 10 started

Time	M. V.	Temp. °C	Remarks
11:45	11.4	805	*11 down* (3 started (?) hard to see) 3 has tipped over on 10 and they are going down together—4 started
11:48	11.55	820	*10 and 3 down* together—17 has gone down previously—just missed it. May have mistaken it for 11 but both are down—18 started.
11:54	11.7	830	*4 down*
11:55	11.8	840	*18 down*

Started.....	6	11	13–2	24	10	18	
Down.....		2	11	10–3	4	18	

Cones 1, 9 and 16 did not deform at all but had a vitreous glossy appearance very similar to those that did deform. On observation three weeks later all had a dull surface probably due to atmospheric action on the soluble compounds.

The large number of cones under observation made it rather difficult to get the exact order of deformation. 3 and 11 appeared to have the least viscosity, 2 and 10 were next. No. 13 was noted as having started. It proceeded no further and was probably due only to shrinkage.

In a general way this burn checks Burn No. 1.

Fourth Burn (Series II).—This burn included 2, 3, 10, 11, 4, 17, 18 and 24 which deformed in Burn No. 3. (Fig. 2-II.)

Started 10:00 A. M. Heated slowly. Put on full heat at 1:00 P. M.

Time	M. V.	Temp. °C	Remarks
1:30	8.5	570	
1:55	10.2	705	
2:00	Power off.	Came on again at 2:30	
2:30	7.5	480	
2:40	8.8	590	
2:55	10.2	705	
3:02	10.8	760	10 started
3:05	11.0	770	2 started—17 started backwards
3:10	11.3	795	3 and 11 started
3:12	11.35	800	*10 down*—17 started forward
3:15	11.5	810	*11 down* just a trifle ahead of *2 and 3*. 4 started
3:19	11.75	835	*17 down*. 18 started
3:20	11.8	840	*4 down*
3:22	11.9	845	*18 down*

Started.....	10	2	2–11	17	4	18	24	
Down.....	10	11	2	3	17	4	18	

From the above data it will be seen that the positions of 10 and 11 are reversed in order. Again 3 and 11 appeared to have least viscosity when observed after removal from furnace. This burn, while not checking Burn No. 3 exactly, does emphasize the fact that the most fusible area

within 10% limits lies within the triangle bounded by No. 4 and points about half way between 2 and 1, and 17 and 22. Burn No. 5 will be confined to these limits and 5% steps will be taken in place of 10%.

Fifth Burn (Series II).—This includes members of entire triaxial bounded by members A, 4 and O, (Fig. 3-II). 5% limits. Started 2 P. M.

Time	M. V.	Temp. °C	Remarks
2:00	2.0	...	
2:25	3.2	...	
3:10	8.7	570	
3:25	9.8	675	
3:40	10.9	765	
3:45	11.1	780	10, L, B, E probably started, hard to see F started
3:50	11.4	805	
3:52	12.0	855	F, E, 10 and B down in order. J, L, M, 2 and O had just started in order given

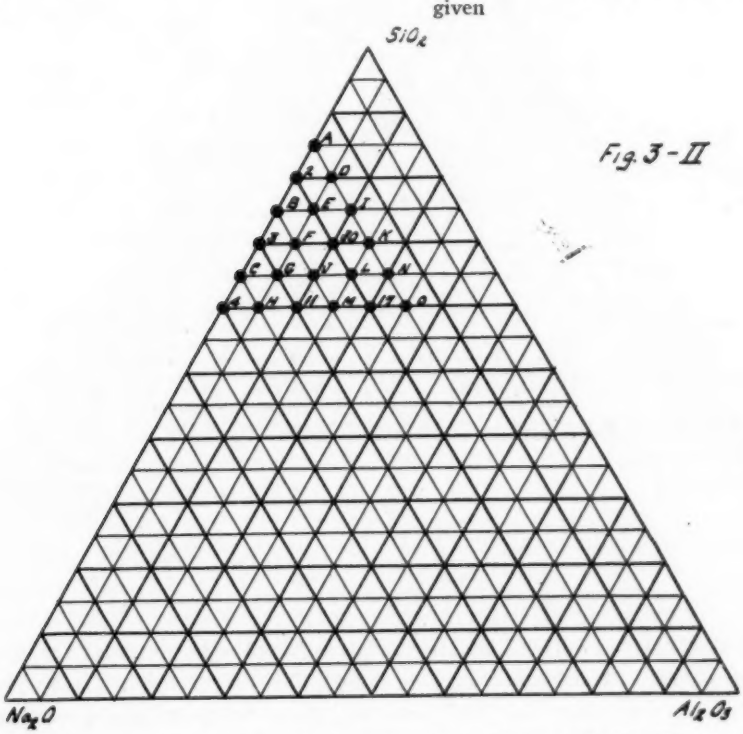


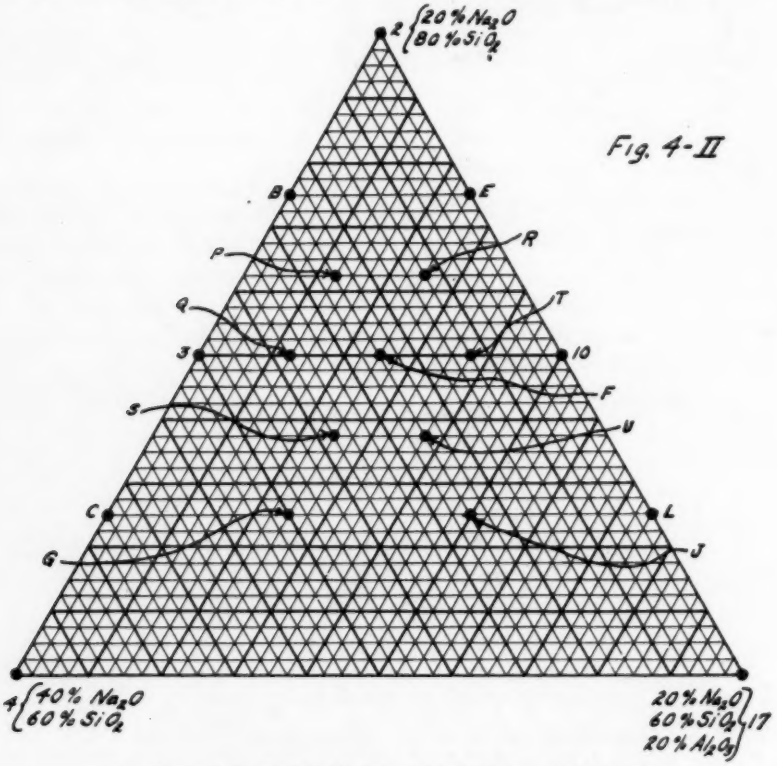
Fig. 3-II

This burn nicely checks previous results. F was decidedly the most fusible, with E next followed by 10 and B which were practically together. With the exception of these four members none of the cones deformed to any great extent. This establishes the fusible area pretty closely. The next burn will be to establish the deformation eutectic as near as possible within $2^1/_2$% limits.

This burn gives B as a eutectic on the straight line Na_2O-SiO_2. In the first two burns of this series a eutectic was indicated at 51.5% Na_2O, 48.5% SiO_2. B has composition 18.4% Na_2O, 81.6% SiO_2. So we have

1. 18.4% Na_2O-81.6% SiO_2 (Na_2O-4.579 SiO_2) 5% limits 860°C.
5. 51.5% Na_2O-48.5% SiO_2 (Na_2O-0.972 SiO_2) 10% limits 830°C.

The above figures are corrected according to analysis of Na_2CO_3.



R—Eutectic—22.50% Na_2O—5.00% Al_2O_3—72.50% SiO_2.
R—Corrected—17.55% Na_2O—5.33% Al_2O_3—77.12% SiO_2.
R—Molecular Formula—Na_2O—0.185 Al_2O_3—4.55 SiO_2.

The only data published on Na_2O-SiO_2 which has come under the observation of the writer is by C. J. Peddle, "The Development of Various Types of Glass. Part I. The Interaction of Silica with the Oxides of Sodium and Potassium."[1] This work deals with solubilities and refractive indices of various compositions. However, the statements are made "Glasses of the type containing more than 75% SiO_2 require temperatures greater than 1300°C for their production." "Glasses containing less than 70% SiO_2 all melt down at temperatures below 900° (C)." He employed

[1] *Loc. cit.*

the following method of fusion: the crucible was heated to desired temperature and material introduced by three fillings at half hour intervals and the batch held at this temperature for $3^1/_2$ hours. He found that the potash glasses reacted at lower temperatures than the soda glasses.

Sixth Burn (Series II).—This brings the limits to $2^1/_2\%$ and includes members F, R, Q, P, U, T, S. (Fig. 4-II.)

Cones were placed in furnace with thermocouple registering 5.5 m. v. at 12:15.

Time	M. V.	Temp. °C	Remarks
12:30	8.8	595	
12:50	10.6	740	
12:53	10.8	760	U started
12:55	11.1	780	R started—P and Q have tilted backwards slightly
12:57	11.2	790	F started
1:00	11.4	805	R down—T started
1:02	11.5	810	Q, S, P started
1:03	11.6	820	U, T, S and F down. Cones removed from furnace

At this point R seems to be the softest with T and U next in order. The cones were placed back in the furnace at red heat (8.6 M. V.) and temperature brought up to deformation point again and held to see if any idea of viscosity could be obtained.

Time	M. V.	Temp. °C	Remarks
2:00	8.6	580	
2:20	10.6	740	
2:25	11.3	800	P down
2:30	11.6	840	Cones removed from furnace

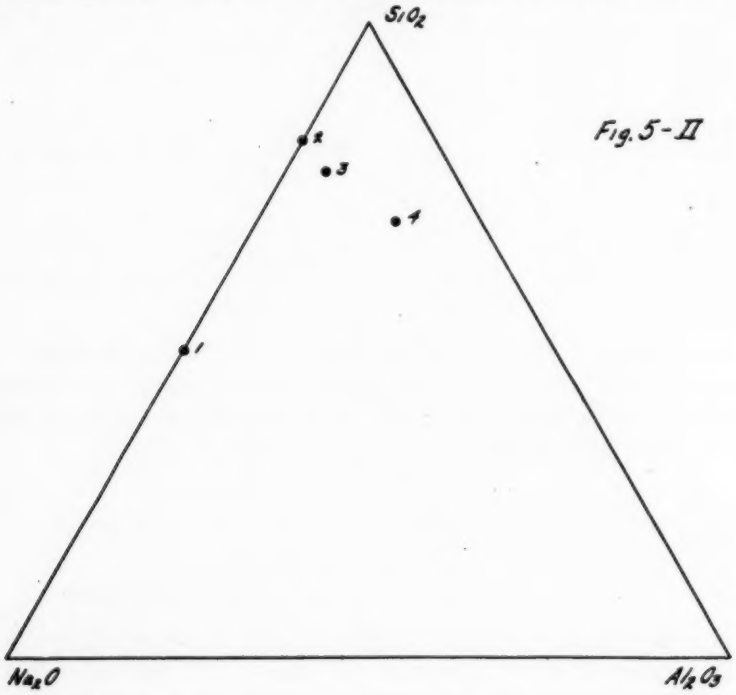
From observation of degree of deformation after the second heating R, F and S appear distinctly softer than the others. Of these three, R seems the softest, followed by F and S in order.

It will be noted that the three softest members lie along a common Al_2O_3 line. This would seem to indicate that Al_2O_3 is the constituent most active in regulating the deformation point.

R is decided upon as the deformation eutectic of the system; Na_2O-Al_2O_3-SiO_2, within $2^1/_2\%$ limits. It must be made plain though that the difference in deformation temperature of three members is small, only a few degrees. Relative deformation was the object in view and exact temperature measurements were not attempted as it would require a high degree of accuracy to ascertain these when the variation in composition is as low as 2.5%.

From the triaxial R has a composition 22.5% Na_2O, 5% Al_2O_3, 72.5% SiO_2 which, when corrected according to analysis, gives 17.55% Na_2O, 5.33% Al_2O_3, 77.12% SiO_2.

One is immediately struck with the fact that the percentage composition is nearly identical with that of the K_2O-Al_2O_3-SiO_2 deformation eutectic and, when methods and raw materials are considered, may be considered the same. The temperatures at which deformation took place are not widely different, 800°C for the soda eutectic and 870°C for the potash. From this it may be said that K_2O and Na_2O have the same fluxing value *pound* for *pound* when introduced in the form of carbonates. This



		Limits	Composition						Appr. def., °C
			Per cent				Molecular		
			Na_2O	Al_2O_3	SiO_2	Na_2O	Al_2O_3	SiO_2	
1	Binary Eutectic	10%	51.5	..	48.5	1.00	..	0.972	830
2	" "	5%	18.4	..	81.6	1.00	..	4.579	860
3	Ternary "	2½%	17.55	33.5	77.12	1.00	0.185	4.55	800
4	Pure Soda Spar		11.83	19.47	68.70	1.00	1.00	6.00	1250

is in accord with the statement made by Homer F. Staley,[1] "When introduced from corresponding soluble salts, Na_2O and K_2O, are equivalent, pound for pound."

In working out the CaO-Al_2O_3-SiO_2 and MgO-Al_2O_3-SiO_2 eutectics

[1] *Trans. Amer. Ceram. Soc.*, **13**, 504 (1911).

the Geophysical Laboratories found two areas of low fusibility towards the SiO_2 end of each triaxial. In the case of the former there was one near the CaO-SiO_2 line and in the case of the latter, near the MgO-SiO_2 line, these points corresponding somewhat to those found in the Na_2O-Al_2O_3-SiO_2 and K_2O-Al_2O_3-SiO_2 triaxials. They also found points approaching the Al_2O_3-SiO_2 line in both cases which leads one to believe there might be similar points in the Na_2O-Al_2O_3-SiO_2 and K_2O-Al_2O_3-SiO_2 triaxials. The field was not carefully studied to see if such exist because the temperatures were much higher and the low temperature points established were the ones desired.

Conclusions

1. The members toward the high Na_2O corner with an Na_2O content above that of member No. 5 have a stony or slag-like appearance and are not glossy like those toward the high SiO_2 end.

2. Two deformation eutectics are found on the straight line Na_2O-SiO_2

(*a*)	51.5% Na_2O	(*b*)	18.4% Na_2O
	48.5 SiO_2		81.6 SiO_2
	(830°C)		(860°C)

3. A ternary deformation eutectic was found of the composition:

17.55 Na_2O
5.33 Al_2O_3
77.12 SiO_2

4. The deformation temperature of this eutectic is 800°C and approaches that of a glass or enamel. It is close to that of K_2O-Al_2O_3-SiO_3 eutectic which was 870°C.

5. This eutectic has a lower alumina content than any natural sodium-aluminum-silicate mineral known.

6. The composition of the ternary eutectic is practically the same in percentage composition by weight as that of the K_2O-Al_2O_3-SiO_2 system. Consequently it may be said that Na_2O and K_2O have the same fluxing value pound for pound when introduced in the form of carbonates.

RESEARCH LABORATORIES
ELYRIA ENAMELED PRODUCTS CO.
ELYRIA, OHIO

THE CONTINUOUS SYSTEM OF GRINDING CERAMIC MATERIALS[1]

By Harlowe Hardinge

Introduction

It is well to point out at the outset that we make no claim of being ceramic engineers with a knowledge of the industry as a whole. We have been called specialists, and perhaps that is the best term to use in this instance, as we specialize in one branch only of this most important industry. I mention this point now in an endeavor to make it clear that what we have done in the matter of grinding various materials required in the ceramic industry, has been accomplished through our knowledge of grinding and what can be done under given conditions. We are not trying to alter the conditions as they exist, but simply point out a method whereby the information we have obtained from many years' experience in other fields may be used to advantage in the ceramic industry.

The methods which I am about to describe are not experiments, unless one might consider every installation an experiment due to the conditions surrounding each as being different from its neighbor. Our work has been directed to both the wet grinding and dry grinding of the many materials. This discussion, however, will deal mainly with feldspar, silica, grog, and enamel frit, as these are typical materials illustrating the new methods which are now being applied with considerable success.

Feldspar and Silica

Taking up first the most important of these fields, that is, the grinding of feldspar, what I am endeavoring to show is a method known in a general way by many, but fully comprehended by comparatively few, as it has only recently been introduced into the ceramic industry. This is the "continuous" system of grinding. There are a number of methods which have been used in the past which might be considered as semi-continuous, but to my knowledge none have been entirely continuous, especially where fine grinding is required.

The application of the continuous system for grinding silica is similar to that of feldspar, hence the systems herein described for the grinding of feldspar will apply to the grinding of silica whether wet or dry, and in fact, are being used today under almost parallel conditions.

Rather than take a hypothetical case, I have obtained permission to use as an illustration an actual installation now in successful operation and will give the facts as they are today. The installation which I will describe

[1] Paper presented before the American Ceramic Society at the Exposition of Chemical Industries, New York City, September 15, 1922.

is that of the Golding-Keene Company, Keene, N. H., which is grinding feldspar dry.

Mine

The Keene Mica Products Company is operating a feldspar property located about 11 miles from Keene, N. H., and is selling their product to the Golding-Keene Company at Keene, N. H. The former company has been operating the property for a number of years for the mica which occurs along the walls of a feldspar dike. This feldspar dike is about 50 to 100 feet wide and has been traced over an entire hillside.

The property was developed by opening up a large pit on the feldspar dike and later drifting in along the dike. The bench system of mining similar to that employed in limestone mining, is used. The pit is about 100 feet across and about 75 feet deep. Another pit similar to the first one is being opened about 300 feet away and directly on the dike. Drifting will be done on this opening to meet the tunnel from Pit No. 1. The deposit has been thoroughly prospected and the estimate that 500,000 tons of feldspar are in sight is conservative.

Being at rather a high altitude for this section of the country, very little water is encountered, therefore no pumping is necessary. The feldspar is shot down from the benches with dynamite, the holes for which are drilled with air drills.

The feldspar is then sorted into two grades according to silica and mica content, No. 1 being the purer grade. This sorting is accomplished at the mine by hand cobbing. At present, the feldspar is hoisted by means of a bucket and steam hoisting derrick and deposited in bins alongside the roadway. The drifts are not advanced far enough to necessitate hauling the feldspar to the pit opening, but as soon as these have advanced to where they will not permit of loading directly into the buckets, the feldspar will be loaded into mine cars and trammed to the opening.

Milling Plant

The milling machinery is installed in one of the brick buildings of the Keene Mica Products Company, at Keene, N. H. The feldspar is hauled from the mine 11 miles away by motor trucks.

The mill building contains the crude storage or crushing room and the grinding room. The feldspar is stored on the floor of the storage room into separate piles of No. 1 and No. 2 feldspar. The following are analyses of their two grades of feldspar:

		Analysis of No. 1 feldspar, "Puritan"	Analysis of No. 2 feldspar, "Keene"
Silica	SiO_2	66.45%	69.59%
Alumina	Al_2O_3	19.45	16.99
Lime	CaO	.00	.65

Iron oxide	Fe_2O_3	0.07	0.09
Magnesia	MgO	.11	.27
Potash	K_2O	11.04	10.20
Soda	Na_2O	2.75	1.68
Loss in ignition		.15	0.70
		100.02	100.17

From the storage piles, the feldspar is fed into a 9″ x 16″ Reliance jaw crusher, equipped with flat manganese steel jaw plates, designed for fine crushing and set to deliver $^1/_2$-in. product. This crusher is driven from a 20-horse power motor and discharges its product into an elevator equipped with manganese steel buckets to eliminate any chance for iron contamination. The elevator lifts the crushed feldspar to a 20-ton storage bin.

The crushed material is fed by means of a regulating disc and manganese steel chute feeder into an 8-ft. diameter by 36-in. cylinder Conical Pebble Mill. The top of the disc measuring feeder is covered with hard wood to eliminate the introduction of any metallic substances, and the feed table itself is driven by chain drive from the mill countershaft. The mill is especially designed for dry grinding, having 23-in. diameter main bearings which are water-jacketed for water-cooling. The mill countershaft is driven from a 60-horse power slip ring, 685 r. p. m. full load speed General Electric motor through a Link-Belt silent chain drive. The mill itself is equipped with a 136-tooth, 9-ft. diameter by 8-in. face gear and this gear is driven from a 17-tooth pinion on the countershaft. The discharge end of the mill is equipped with a circular wire screen about 18 inches long and 24 inches in diameter with about $^1/_4$-in. square openings. The purpose of this screen is to catch broken pebbles or coarse lumps and keep them from going into the circuit. It also serves to act as an indicator as to whether or not the mill is being overfed. Presence of a great many coarse lumps in this trommel is an indication of overfeeding.

The mill is operated at a speed of 27 r. p. m. and carries a pebble charge of

5,000 pounds	5 inches
3,000 pounds	4 inches
3,000 pounds	3 inches
1,800 pounds	2 inches
Total 12,800	

The feed to the mill runs about as follows:

Through 1-in. ring	100%
Through 2-mesh	89.9%
Through 4-mesh	61.8%
Through 12-mesh	43.8%

The moisture in the feed averages about 2% by weight.

The product discharged from the mill is elevated to a 14-ft., Model

21, Gayco Emerick air separator by means of a belt and bucket elevator equipped with manganese steel buckets. This elevator feeds a short belt conveyor feeding the air separator. The feed to the air separator runs as follows:

Through 140-mesh	70 to 80%
Through 200-mesh	55 to 60%
Through 300-mesh	40 to 50%

The product coming from the separator runs as follows:

Through 140-mesh	99.8%
Through 200-mesh	96 to 98½%
Through 300-mesh	91 to 92%

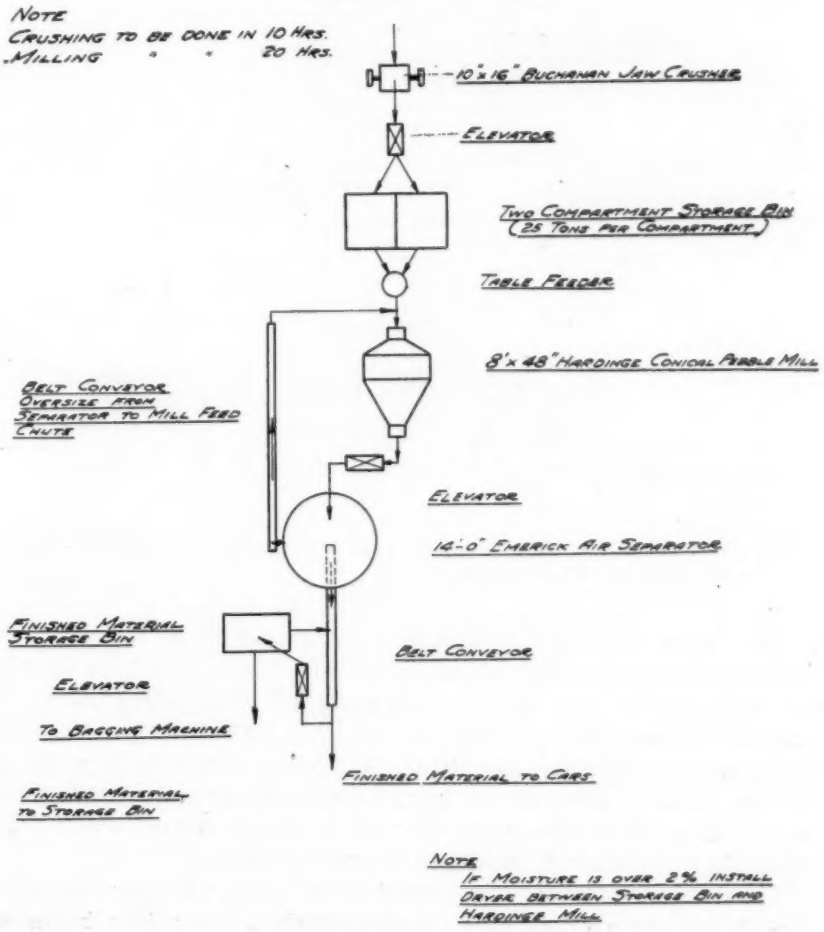

NOTE
CRUSHING TO BE DONE IN 10 HRS.
MILLING " " 20 HRS.
10"x16" BUCHANAN JAW CRUSHER
ELEVATOR
TWO COMPARTMENT STORAGE BIN (25 TONS PER COMPARTMENT)
TABLE FEEDER
8'x48" HARDINGE CONICAL PEBBLE MILL
BELT CONVEYOR OVERSIZE FROM SEPARATOR TO MILL FEED CHUTE
ELEVATOR
14'-0" EMERICK AIR SEPARATOR
FINISHED MATERIAL STORAGE BIN
BELT CONVEYOR
ELEVATOR
TO BAGGING MACHINE
FINISHED MATERIAL TO CARS
FINISHED MATERIAL TO STORAGE BIN
NOTE
IF MOISTURE IS OVER 2% INSTALL DRYER BETWEEN STORAGE BIN AND HARDINGE MILL

FIG. 1.—Arrangement of a feldspar or silica grinding plant having a capacity of 1½ to 2 tons per hour.

The capacity of the mill and separator delivering this product is 2,600 pounds per hour, although at times it is possible to go up to 2 tons per hour. The coarse tailings from the separator are discharged on to a belt conveyor which returns them to the feed table ahead of them all. Tests show that the air separator takes 85% to 90% of the 140-mesh and finer material out of the mill discharge. No matter what the condition of the feed to the air separator is in, the separator continues to deliver a uniform product having the same fineness.

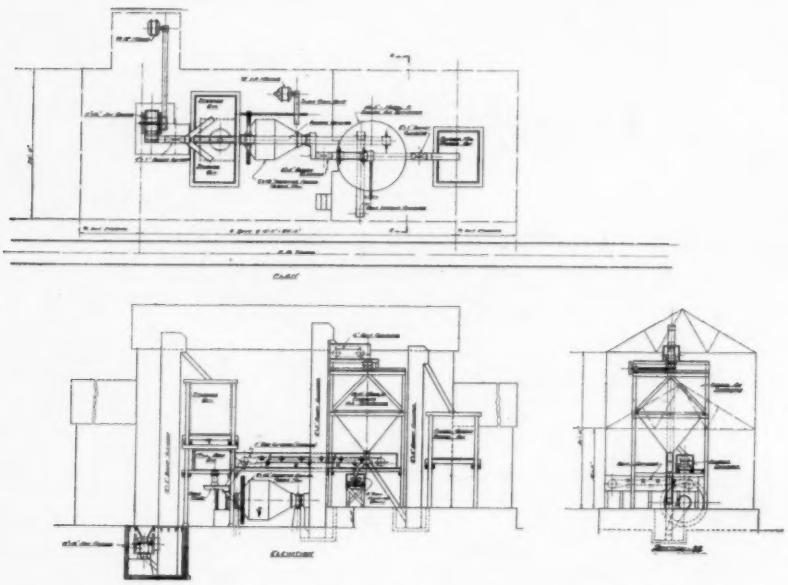


FIG. 2.—General arrangement of a simple feldspar or silica grinding plant having a capacity of $1^1/_2$ to 2 tons per hour.

The Gayco Emerick air separator consists briefly of an outer shell with separating chamber, tailings cone, baffle plates, feed pipe on which are attached the fans, driving mechanism and distributing plate. The main fan causes a lifting action while the small fan in the separating chamber causes a centrifugal separation. By various adjustments on the centrifugal fans, the resultant of the two forces, lifting and centrifugal, can be varied to obtain almost any fineness of product desired which is little affected by atmospheric changes or variations in feed.

The finished material is discharged on to a belt conveyor which feeds directly into the box cars or into an elevator which in turn lifts the material to a storage room.

The Gayco Emerick air separator takes about 10 h. p. and operates at

a countershaft speed of 250 r. p. m. which causes a fan speed of 160 r. p. m. The elevators and belt conveyors take about 10 h. p. more, and actual readings on the Hardinge mill motor showed that this mill is taking 55 h. p. The entire installation is consuming about 90 h. p., but the jaw crusher crushes enough on a 12-hour shift to keep the mill running 24 hours.

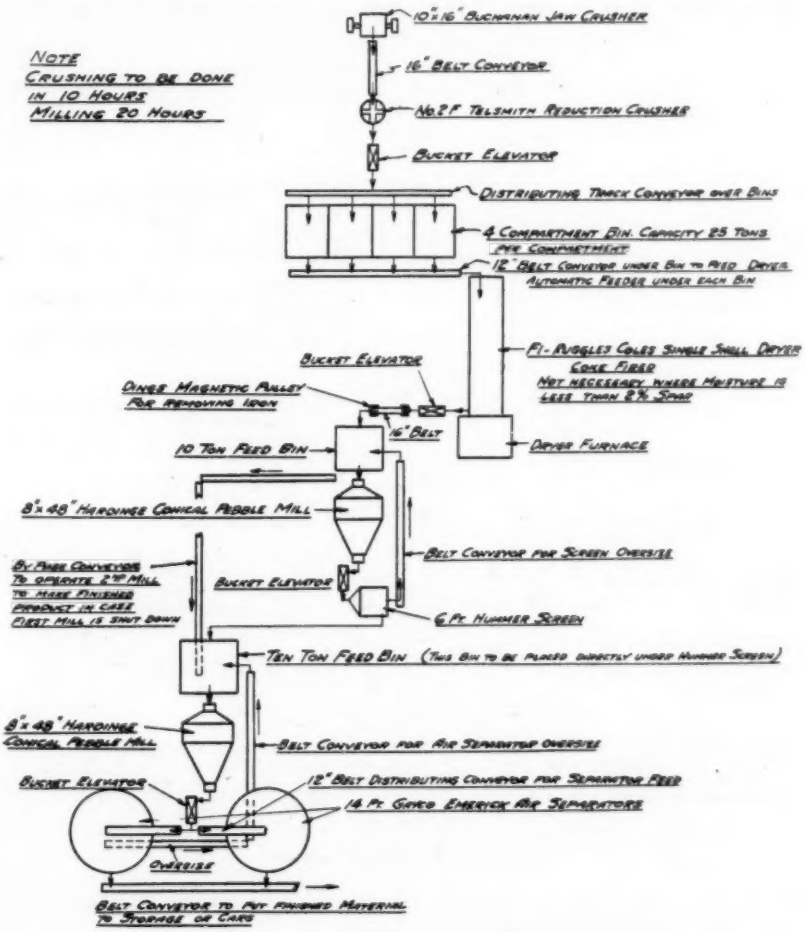

NOTE
CRUSHING TO BE DONE IN 10 HOURS
MILLING 20 HOURS
10"x16" BUCHANAN JAW CRUSHER
16" BELT CONVEYOR
No. 2 F. TELSMITH REDUCTION CRUSHER
BUCKET ELEVATOR
DISTRIBUTING TRUCK CONVEYOR OVER BINS
4 COMPARTMENT BIN. CAPACITY 25 TONS PER COMPARTMENT
12" BELT CONVEYOR UNDER BIN TO FEED DRYER. AUTOMATIC FEEDER UNDER EACH BIN
FT. RUGGLES COLES SINGLE SHELL DRYER COKE FIRED NOT NECESSARY WHERE MOISTURE IS LESS THAN 2% SPAR
BUCKET ELEVATOR
OVER MAGNETIC PULLEY FOR REMOVING IRON
16" BELT
DRYER FURNACE
10 TON FEED BIN
8'x48" HARDINGE CONICAL PEBBLE MILL
BELT CONVEYOR FOR SCREEN OVERSIZE
BY PASS CONVEYOR TO OPERATE 2ND MILL TO MAKE FINISHED PRODUCT IN CASE FIRST MILL IS SHUT DOWN
BUCKET ELEVATOR
6 FT. HUMMER SCREEN
TEN TON FEED BIN (THIS BIN TO BE PLACED DIRECTLY UNDER HUMMER SCREEN)
8'x48" HARDINGE CONICAL PEBBLE MILL
BELT CONVEYOR FOR AIR SEPARATOR OVERSIZE
BUCKET ELEVATOR
12" BELT DISTRIBUTING CONVEYOR FOR SEPARATOR FEED
14 FT. GAYCO EMERICK AIR SEPARATORS
OVERSIZE
BELT CONVEYOR TO PUT FINISHED MATERIAL TO STORAGE OR CARS

FIG. 3.—4-ton per hour dry grinding plant for feldspar or silica using Hardinge Mills and Emerick air separators.

Aside from a few minor troubles with auxiliary machinery, this plant has operated steadily since its start about three months ago.

They recently decided to increase the capacity by installing an 8-ft. diameter by 48-in. cylinder Hardinge Conical Pebble Mill and another 14-ft. Gayco Emerick air separator. The new unit is calculated to give

them 2 tons per hour and will be installed beside the existing grinding unit.

Fig. 1 shows the arrangement of a typical unit which is very similar to that described above. Fig. 2 is a drawing of the plan and elevation of such a unit.

I feel greatly indebted to the management of the Golding-Keene Co. and am very glad to express my appreciation for their allowing me the

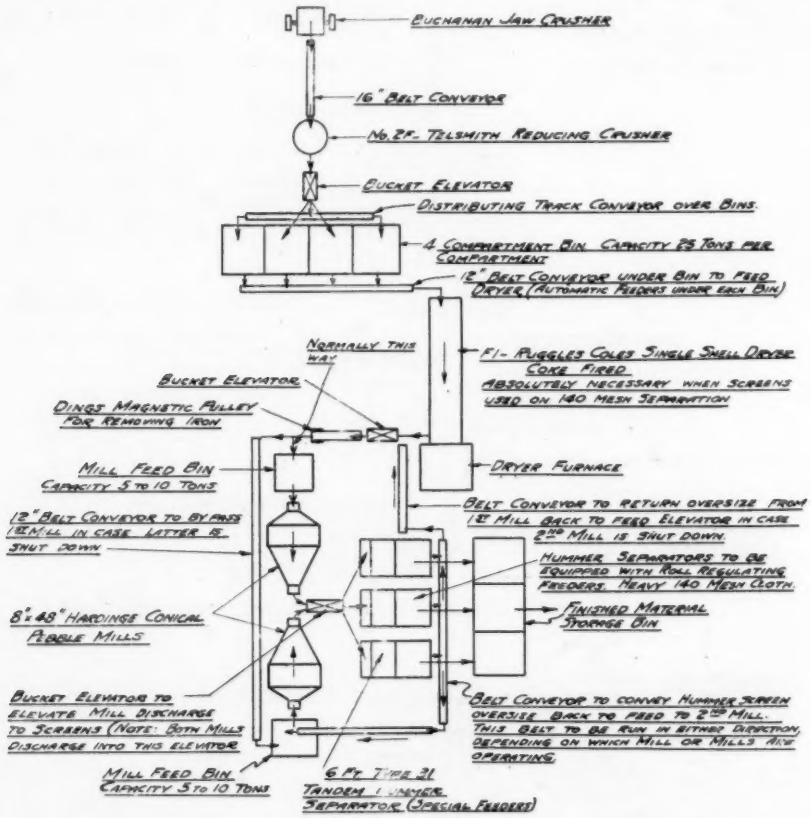

BUCHANAN JAW CRUSHER
16" BELT CONVEYOR
No. 2F. TELSMITH REDUCING CRUSHER
BUCKET ELEVATOR
DISTRIBUTING TRACK CONVEYOR OVER BINS
4 COMPARTMENT BIN. CAPACITY 25 TONS PER COMPARTMENT
12" BELT CONVEYOR UNDER BIN TO FEED DRYER (AUTOMATIC FEEDERS UNDER EACH BIN)
NORMALLY THIS WAY
BUCKET ELEVATOR
DINGS MAGNETIC PULLEY FOR REMOVING IRON
MILL FEED BIN CAPACITY 5 TO 10 TONS
12" BELT CONVEYOR TO BY PASS 1ST MILL IN CASE LATTER IS SHUT DOWN
8' x 48" HARDINGE CONICAL PEBBLE MILLS
BUCKET ELEVATOR TO ELEVATE MILL DISCHARGE TO SCREENS (NOTE: BOTH MILLS DISCHARGE INTO THIS ELEVATOR
MILL FEED BIN CAPACITY 5 TO 10 TONS
6 FT. TYPE 21 TANDEM AIR SEPARATOR (SPECIAL FEEDERS)
F1- RUGGLES COLES SINGLE SHELL DRYER COKE FIRED ABSOLUTELY NECESSARY WHEN SCREENS USED ON 140 MESH SEPARATION
DRYER FURNACE
BELT CONVEYOR TO RETURN OVERSIZE FROM 1ST MILL BACK TO FEED ELEVATOR IN CASE 2ND MILL IS SHUT DOWN
HUMMER SEPARATORS TO BE EQUIPPED WITH ROLL REGULATING FEEDERS. HEAVY 140 MESH CLOTH
FINISHED MATERIAL STORAGE BIN
BELT CONVEYOR TO CONVEY HUMMER SCREEN OVERSIZE BACK TO FEED TO 2ND MILL. THIS BELT TO BE RUN IN EITHER DIRECTION, DEPENDING ON WHICH MILL OR MILLS ARE OPERATING.

FIG. 4.—3- to 4-ton per hour plant for grinding feldspar and silica by the dry process, using Hardinge Mills with electric screens.

opportunity of describing to the members of the AMERICAN CERAMIC SOCIETY the operation of their plant.

General

It might be well to consider in passing that all conditions are by no means the same but the layouts of typical plants as here illustrated should insure a satisfactory product under all conditions and in all climates.

The layout shown in Fig. 3 is that of a complete plant grinding feldspar at the rate of 4 tons per hour. A drier is included in order to insure a dry feed under all climatic conditions. It should be noted that during normal operation the first mill is operated in closed circuit with a vibrating screen of relatively coarse mesh, the oversize of this screen going back to the preliminary mill for regrinding and the fine material going to the re-

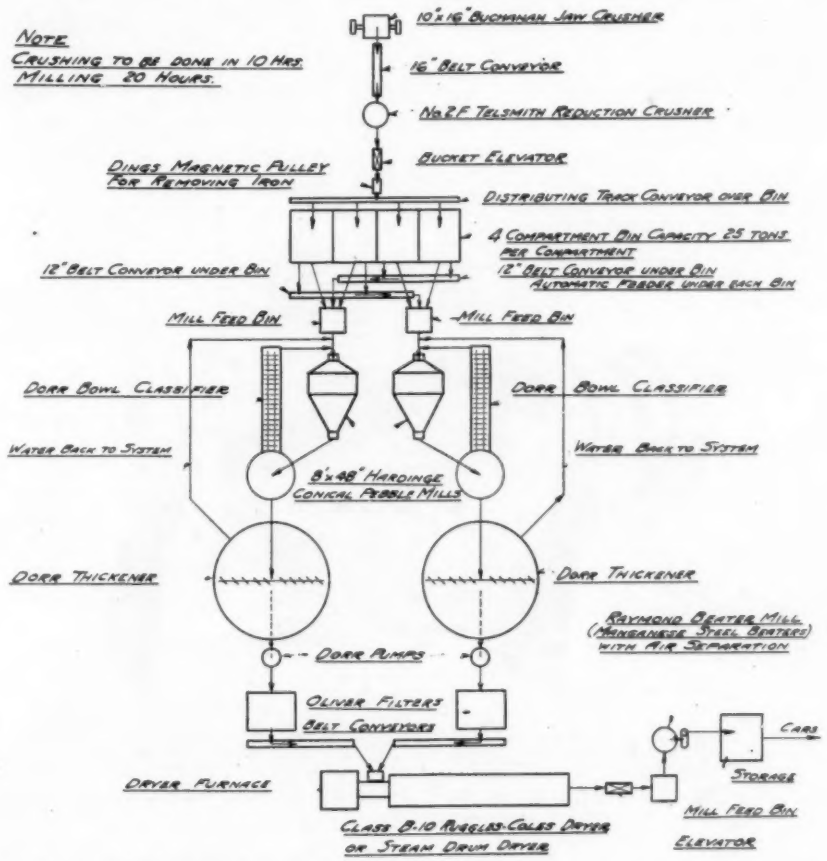


FIG. 5.—Typical layout of a wet grinding feldspar or silica plant having a capacity of 4 tons per hour.

grinding mill which is in turn in closed circuit with air separators. This layout has many advantages in that the drier not only insures a satisfactory feed to the mills in all kinds of weather but also increases the capacity of the grinding units. Note that in this instance, 8-ft. diameter by 48-in. cylinder pebble mills are used instead of an 8-ft. diameter by 36-in. cylinder mill as described in the plant of the Golding-Keene Company.

Fig. 4 illustrates another arrangement of a plant having the same capacity as the previous one, namely 4 tons per hour, but instead of using air separators, vibrating screens are employed. Here the arrangement of the milling unit is somewhat different. You will note that both mills may take the initial feed and discharge their product to screens, or in other words, each mill may take half the capacity of the plant, or the entire product may be sent to the first mill, then its product passed over the screens, the oversize going to the second mill whose product also goes over the fine screens.

Fig. 5 illustrates a method of grinding feldspar by the wet process. This is a very good method, is economical to operate, and clean, but re-

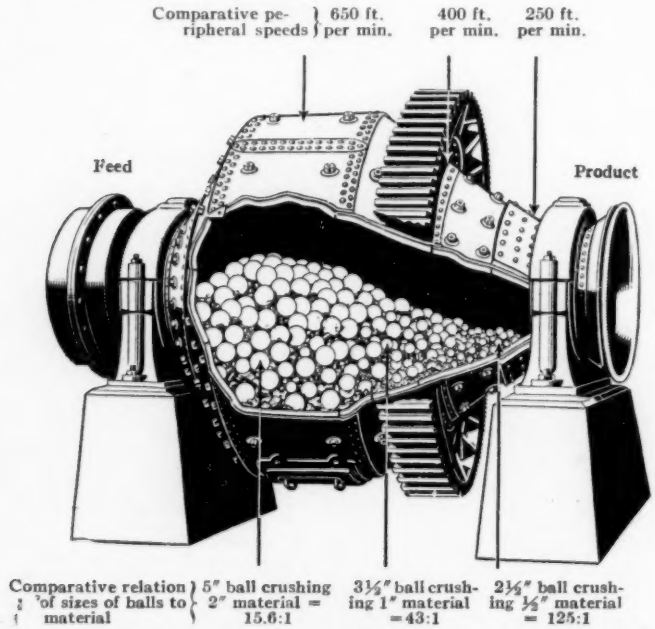

Comparative peripheral speeds
650 ft. per min.
400 ft. per min.
250 ft. per min.
Feed
Product
Comparative relation of sizes of balls to material
5″ ball crushing 2″ material = 15.6:1
3½″ ball crushing 1″ material = 43:1
2½″ ball crushing ½″ material = 125:1

Fig. 6.—Illustration of the classification of balls and material within the Conical Mill.

quires a larger initial investment. Here driers must be used, for the finished product as it comes from the filters contains too much moisture, while in the dry process, driers are not absolutely essential to successful operation especially when the moisture content of the feldspar going to the crusher is approximately 2%.

Grinding of Grog

The grinding of grog as recently developed is a far cry from that of feldspar but here again modifications of the method of treatment effect marked

economies where the grinding must be 10-mesh or finer. By using the Conical Ball Mill operated in conjunction with a revolving screen on the end of the mill or an outside vibrating screen, especially where products finer than 10-mesh are desired, the operation becomes simple and dustless. There is no denying that dry pans used for the grinding of grog to a product up to 6- or 8-mesh are more efficient than anything ever attempted, but

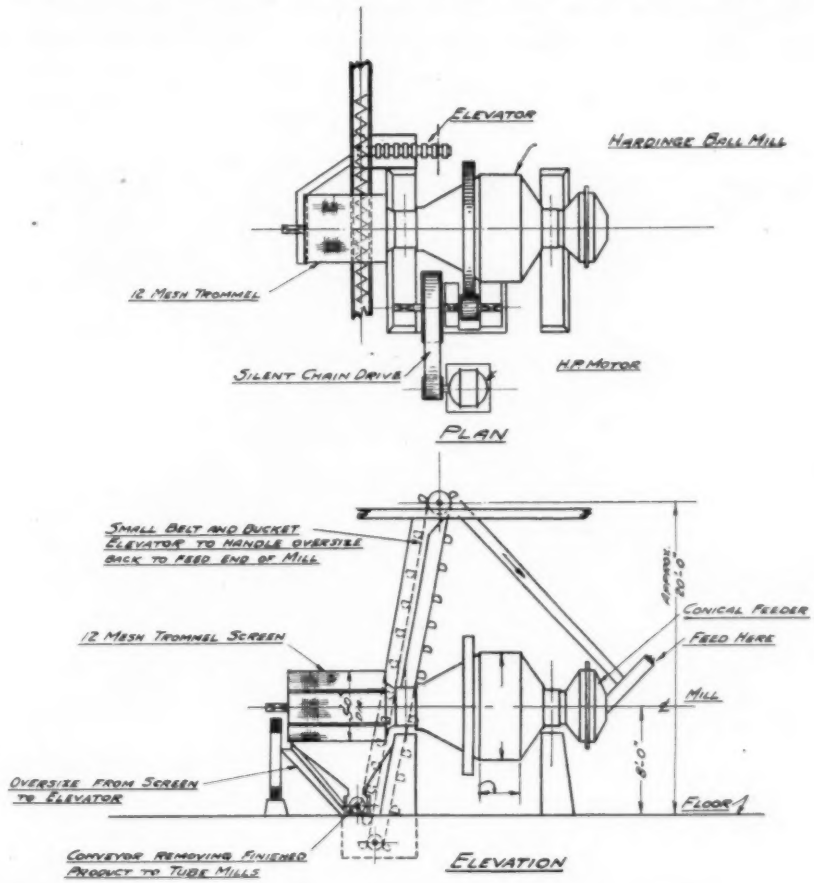


FIG. 7.—General arrangement of a Hardinge Ball Mill using heavy steel balls for grinding grog or Hardinge Pebble Mill using flint or porcelain pebbles for grinding enamel frit.

when it comes to grinding finer than 10-mesh, the whole aspect changes and it is just here where your attention is called to the application of the Conical Mill for accomplishing this work.

The Conical Mill in this case is usually supplied with steel balls and metal lining. Some of the balls used weigh as much as 20 pounds each. Before

we take up the results, it is well to consider how the mill operates so as to insure a product of the right characteristics and fineness. Usually it is desirable to have this product as uniform as possible and containing particles having sharp corners.

Owing to the action which occurs in the Conical Mill by virtue of the segregating effect which occurs in the cone, it will be found that as soon as the material has been ground, it travels very rapidly towards the discharge cone as it is unimpeded in its travel. This avoids overgrinding

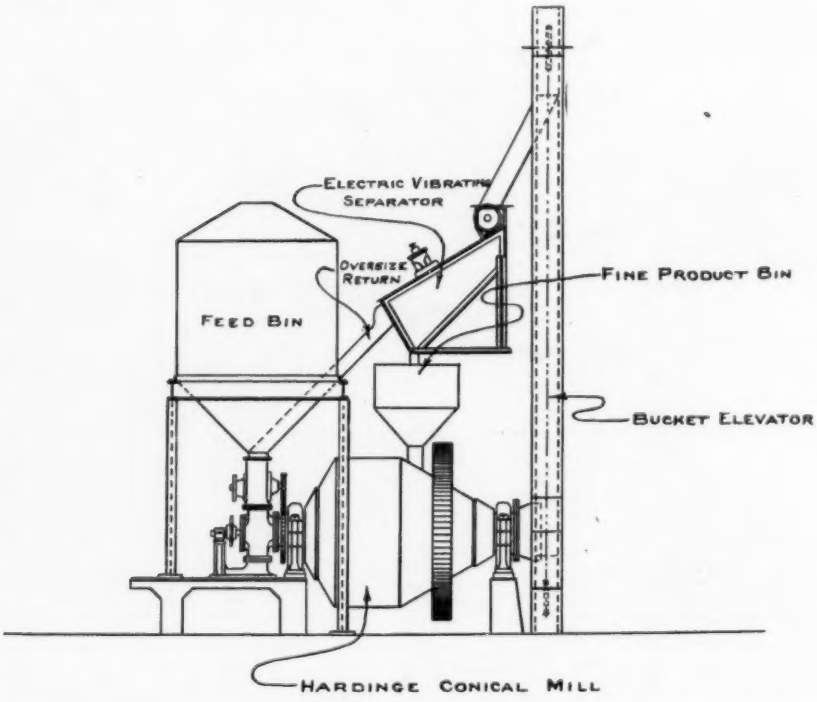


FIG. 8.—Typical arrangement of a unit consisting of a Hardinge Mill and electric screen for the grinding of enamel frit.

and it is for just this reason that the proper product is obtained at a high capacity compared with the power expended. (See Fig. 6.) The material discharged from the mill contains a far greater quantity of finished material than is the case with the ordinary dry pan. This reduces the load on the screens and consequently reduces screening and elevator troubles. The mill being entirely enclosed is dustless in operation, and since the grinding media are balls crushing against the heavy metal lining, the wear is very slight; in fact, in one case I have in mind where harder material than ordinary grog is being ground to the same specifications, a mill has been

operating for five years and the maintenance charges have been so small that, except for ball wear which amounts to $^1/_{10}$ lb. per ton, or about six tenths of a cent per ton, they cannot be estimated.

As an illustration of what this mill will do, a 5-ft. Conical Ball Mill taking a feed of 2 inches consisting of broken fire brick, pots, etc., will ordinarily have a capacity of about 3 tons per hour delivering a product all through 16-mesh and requiring about 35 h. p., the mill of course operating in conjunction with a screen, the oversize being returned for regrinding. Where a coarser product is desired, the capacity is considerably increased as might be expected. Fig. 7 illustrates a typical layout.

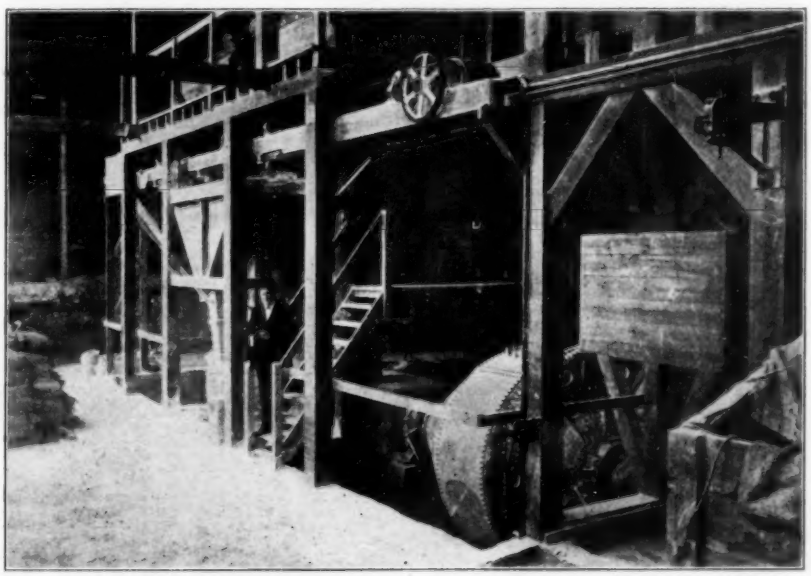


Fig. 9.—General view of the mill operated by the Cleveland Feldspar and Products Co.

Grinding Enamel Frit

The Conical Mills for grinding enamel frit, unlike those for grinding grog, are usually lined with porcelain or silica to prevent any possible iron contamination, the grinding media being flint or porcelain pebbles. Instead of employing the ordinary batch system, that is, loading the mill through a manhole, then closing up and running for a number of hours, finally dumping the mill and shoveling into a screen, the operation consists simply of dumping in a quantity of the frit at the feed hopper of the mill, the feed then automatically entering the mill and after being ground passes out of the discharge at a continuous rate. It is usually found best

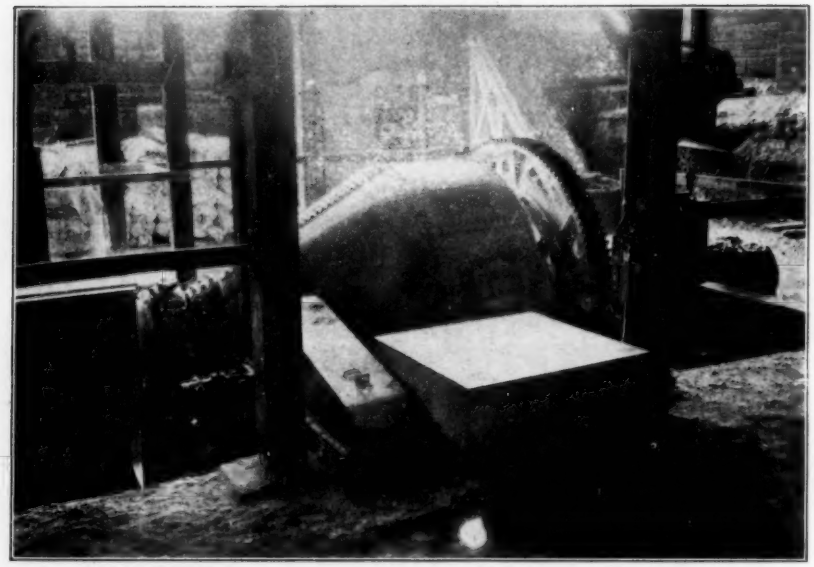


Fig. 10.—Pebble Mill operated by motor with chain drive, a very satisfactory method.

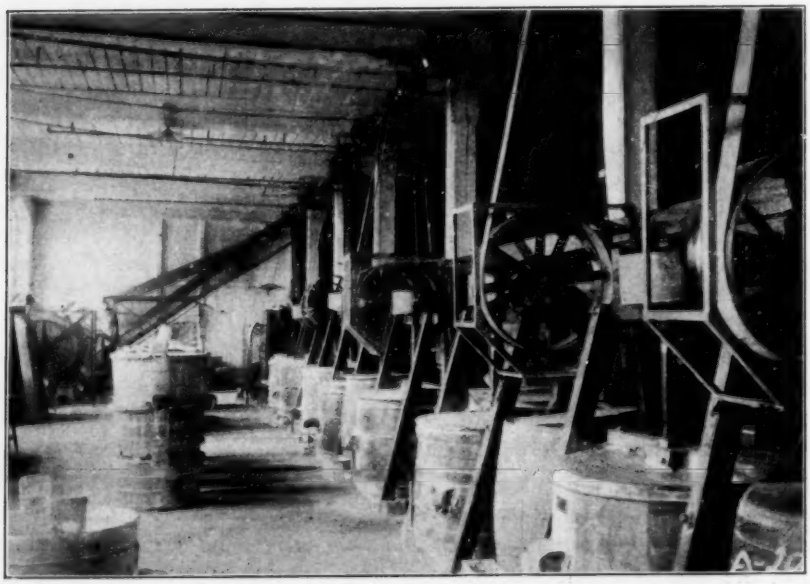


Fig. 11.—Old grinding tubes replaced by the Conical Mill and bowl classifier.

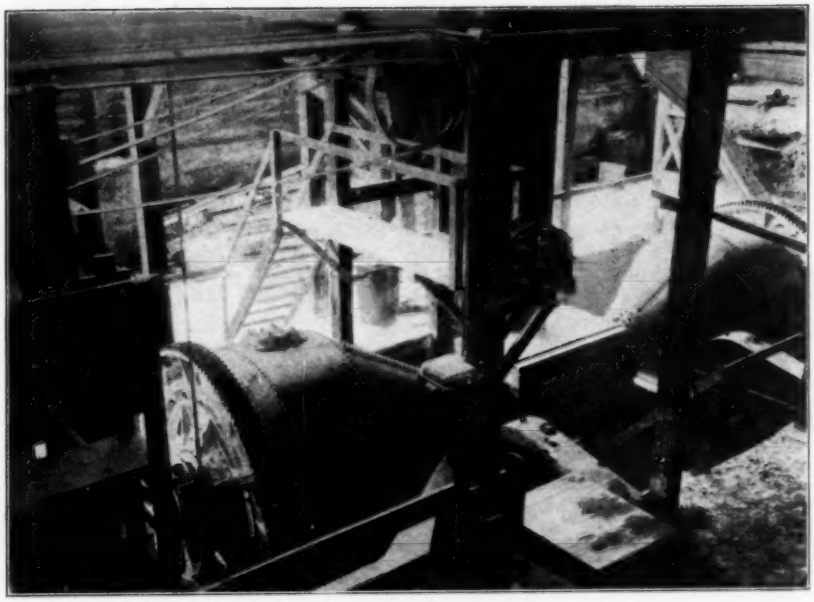


Fig. 12.—Arrangement of Conical Mills in a plant grinding feldspar dry.

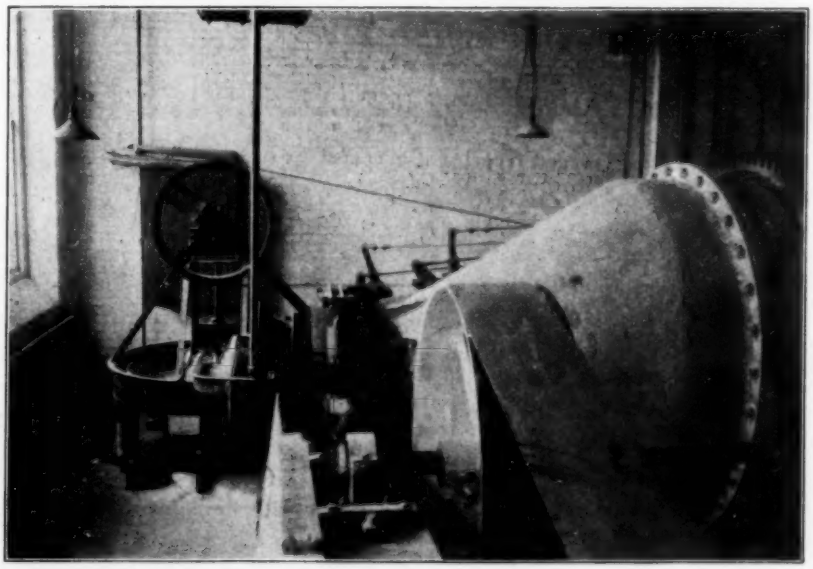


Fig. 13.—Conical Mill operating in "closed circuit" with a Dorr bowl classifier for grinding feldspar by the wet process.

to place a small trommel screen at the end of the mill, or where the capacities are relatively large, to use an outside separating device, the oversize going back to the mill for regrinding; thus the finished product is absolutely uniform containing no coarse pieces. This system eliminates a great deal of the handling and reduces the possibility of foreign substances getting into the finished product. The great advantage aside from the reduction in labor cost is the reduction in power for a given capacity.

One of the largest manufacturers of sanitary ware in the United States is operating an 8-ft. diameter by 30-in. cylinder Conical Pebble Mill in conjunction with a screen, taking the dry quenched frit, at a capacity of 2,000 pounds per hour, or 20,000 pounds per day, reducing the frit to a fineness of 100% through 60-mesh, with about 70% through 200-mesh, and requiring 50 h. p. One man easily handles this entire operation; in fact, is free to care for other equipment nearby.

Where capacities of 4,000 pounds or more per day are required, the economies are quite marked as compared with the ordinary batch process.

The accompanying layouts, Figs. 7 and 8, show the systems used. Fig. 7 illustrates how the trommel is connected to the mill for ordinary use and Fig. 8 illustrates the method of operating in conjunction with a vibrating screen for higher capacities and finer products.

Other Materials

There are a number of other materials commonly ground in the ceramic industry which are used more or less extensively, many of which can be and are being ground very economically by the continuous process, but as the method of grinding these other materials is very similar to those already described, with only slight modifications, they will not be taken up in detail at this time.

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THE VALUE OF SCREEN ANALYSIS IN CERAMICS

By F. P. Nickerson

ABSTRACT

The development of equipment for classifying materials according to size. The importance of classification and proportioning of size of particles in products made from ground or crushed material.

The advantages in screen analysis, of testing sieves with openings made to a fixed ratio.

The advantages of logarithmic or direct diagram plotting of screen analysis.

Checking the efficiency and controlling the character of the product obtained from grinding units and checking products whose value is influenced by the size of grain.

Historical Review

Screening, or classification according to size, has been a practice for many centuries, in fact, screening was in vogue when history was recorded in hieroglyphics, and has been definitely referred to by writers in the last two centuries B. C. and the first century A. D., where hides with holes punched through them were used.

Agricola indicates that a considerable improvement has been made in the screening process, in his work "De Re Metallica," written A. D. 1556, wherein he describes the sieve as "a box made out of planks with holes bored in the planks of the bottom or with iron wires stretched both ways across the bottom of the box and fastened at the intersections with small iron clips."

At this time woven wire screens were also available.

Three illustrations from the many interesting ones in De Re Metallica, serve to remind us that the road to present sizing facilities has been long and arduous.

In the first illustration (Fig. 1) we see the laborious process employed in Agricola's time, of sizing the material from the stamp mill before consigning to the smelter.

The crushed ore was carried down through the plant by gravity, one size of particles being retrieved at each screening level and every time a load was dumped at the top of the chute each successive screen operator empties the residue of his screen in a pile beside him and receives a new charge of unclassified material.

The men in the foreground are sieving with the aid of tubs of water.

Fig. 2 shows two other types of screens used in the 15th century.

The figure in the foreground shows a one-man screening machine, the pole being suspended at one end by a rope, the screen fastened to the pole near the rope and the vibration supplied by the man at the other end of the pole.

In the background is still another type of screen which is suspended in the center and operated by two men.

FIG. 1.

In Fig. 3, Agricola describes this type of sieve as being made of iron wires, hoops and rods.

The operation is continuous as the boy in the picture supplies the screen with the material that is to be washed while the man at the other tub removes that part of the ore that has passed through the sieve. The man at the screen has a regular job.

FIG. 2.

Development of Equipment

The introduction of the steam engine and power driven machinery has been responsible for the gigantic proportions of the present day operations.

Nothwithstanding their quantity production, each year finds us facing the demands for greater efficiency and exactitude in production in all industries.

In industries using ground or crushed material in the body of their product, which undergoes a cementing or fusing process, the size of the particle

that goes to make up the aggregate of that body plays an important part; not only the largest sized particles that just pass the screen, but the proportion of the varied sized particles that go to make up the total.

Therefore, the need for an accurate device for measuring the size of the grain or particle is obvious.

The testing sieve was the outgrowth of the necessity of measuring the size of particles and also determining the proportions of the various sized particles present.

FIG. 3.

The size of opening, the clear space between the wires, and not the mesh, directly determines the size of the product that will pass a testing sieve, for instance, by referring to a wire cloth catalogue, we find that 20-mesh wire cloth is made from sixteen different diameters of wire, ranging from 0.0095 in. to 0.032 in. A 20-mesh sieve made from wire 0.0095 in. in diameter, has an opening 0.0405 in., while a 20-mesh sieve made from 0.032 in. wire has an opening of 0.018 in. When we say "20-mesh" then it may

be any screen with 20 openings to the lineal inch made anywhere from 0.0095 to 0.032 in. wire, with a chance for a variation in the sieve opening from 0.0405 to 0.018 in., a difference of 0.0225 in., so that one person may have 0.018 in. in mind when referring to a 20-mesh screen and another an opening 225% larger or 0.0405 in.

In the United States, it has been the practice to use light or medium grades of wire for testing sieves, while the I. M. M. sieves are made from the heaviest wires it is possible to weave, so that the foregoing is not an exaggerated illustration of the confusion that arises from the use of the term "mesh" in reference to a sieve that is to be used as a standard of measure.

Most manufacturers have given up the use of gage numbers and express the diameter of the wire in the decimal fraction of an inch. Let us take another step in advance and refer to testing sieves by the size of opening in decimal fractions of an inch or millimeters.

Instead of "20-mesh," give the opening, as "0.0328 in. testing sieve;" instead of "200-mesh product," say "0.0029 in. or 0.074 mm. product."

Let us think of our testing sieves as a series of openings. What interests us is that the openings are uniform and accurate, and the wire cloth is double-crimped and made from a suitable diameter of wire, so that the wires cannot shift and get out of place when the sieve is put into service.

When we consider testing sieves as a series of openings, the most important thing to decide is the relationship between these openings. For years those interested in ore dressing and the sizing of products by screens have been using testing sieves with no relationship between the sieve openings, except that the openings either increased or decreased in size. It made a standard of measure without any ratio or relation between the terms of the standard. It was a makeshift, taking whatever meshes and wires could be the most readily furnished.

Fig. 4 shows the openings in the Tyler standard screen scale with a fixed ratio between the openings. This scale is the one with which the most of us are familiar and has as its base an opening 0.0029 in. in diameter—the opening in a 200-mesh screen made of wire 0.0021 in. in diameter, the standard sieve as adopted by the Bureau of Standards of the United States Government—the openings increasing in the ratio of $\sqrt{2}$, or 1.414.

The ratio between the different sizes of the screen scale has been taken as $\sqrt{2}$, or 1.414, as recommended by Rittinger in his work on ore dressing, and the niceness of this will be apparent from the following: taking 0.0029 in. or (0.074 mm.), the opening in the 200 mesh sieve as the base or starting point, the diameter of each successive opening is 1.414 times the opening in the previous sieve.

It also makes the area or surface of each successive opening in the scale just double that of the next finer or half that of the next coarser sieve. In

other words, the diameters of the successive sizes have a constant ratio of 1.414 while the areas of the successive openings have a constant ratio of 2.

Another advantage in this selection of ratio is that by skipping every other screen, the ratio of diameter is 2 to 1; by skipping two sizes the ratio

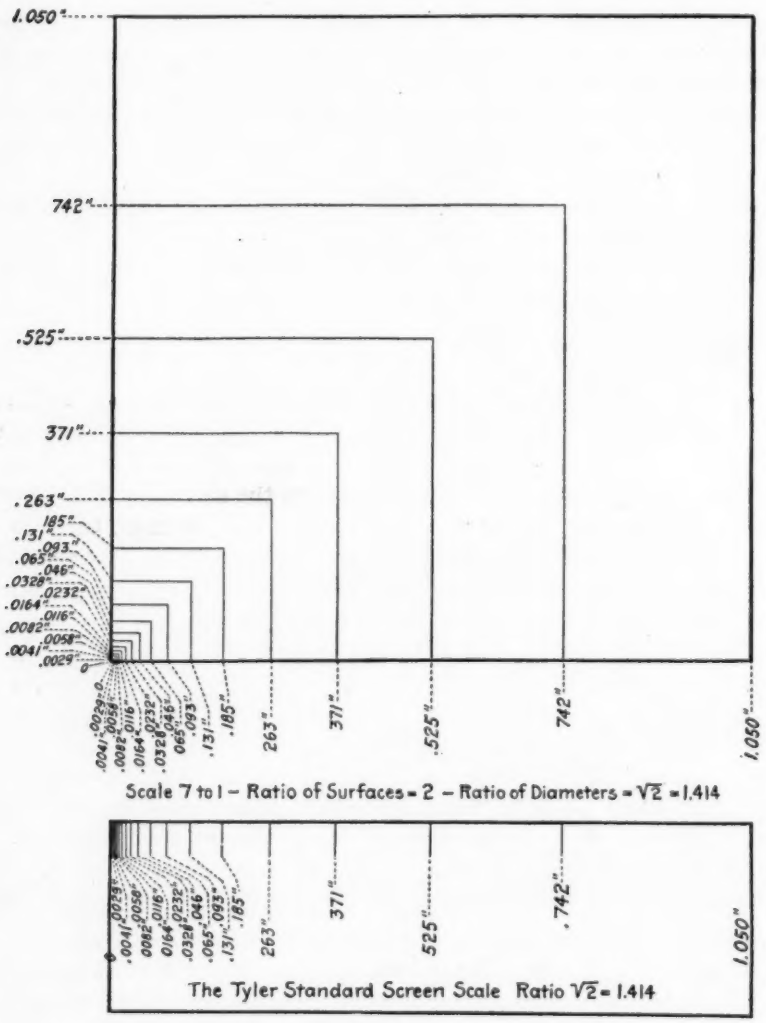

FIG. 4.

is 3 to 1 (approximately); and by skipping three sizes, the ratio is 4 to 1; so that in selecting a screen scale for concentrating work, for instance, one can pick out from the table without any calculation a 1.414, 2, 3 or 4-to-1 ratio of opening.

The openings in this screen scale, from 0.0029 in. (0.074 mm.) to 1.050 in. (26.67 mm.), are shown in Table I, which shows also the mesh and wire that have been used to produce those openings.

The scale can of course be carried further for either finer or coarser screens using the same ratio, but the table covers all the sizes generally used for laboratory work.

In most screen analyses we are more generally interested in the diameter of the various size products, and for this reason we usually think of the scale as a lineal measure. The testing sieve openings are therefore referred to by giving the diameter of the opening instead of its area.

TABLE I

THE TYLER STANDARD SCREEN SCALE

Opening (Ratio $\sqrt{2} = 1.414$) In.	Mm.	Mesh	Diam. of wire, in.
1.050	26.67	...	0.149
0.742	18.85	...	0.135
0.525	13.33	...	0.105
0.371	9.423	...	0.092
0.263	6.680	3	0.070
0.185	4.699	4	0.065
0.131	3.327	6	0.036
0.093	2.382	8	0.032
0.065	1.651	10	0.035
0.046	1.168	14	0.025
0.0328	0.833	20	0.0172
0.0232	0.589	28	0.0125
0.0164	0.417	35	0.0122
0.0116	0.295	48	0.0092
0.0082	0.208	65	0.0072
0.0058	0.147	100	0.0042
0.0041	0.104	150	0.0026
0.0025	0.074	200	0.0021

When it is necessary to carry an analysis finer than 200-mesh, sieves can be supplied as fine as 230-mesh in plain cloth and 325 mesh in twilled cloth.

To provide for a closer sizing where it is necessary in the finer sizes, three intermediate sieve sizes have been added to the screen scale—0.0069 in. (80-mesh), 0.0049 in. (115-mesh) and 0.0035 in. (170-mesh). This produces a screen scale from 0.0029 in. (200-mesh) to 0.0082 in. (65-mesh), the openings in which increase in the series in the ratio of $\sqrt[4]{2}$, or 1.189, the factor recommended by Professor Richards in his work on ore dressing, or the Double Rittinger Ratio. This ratio of diameter or 1.189 makes a difference in the areas between these sizes of about 1.5 times instead of 2 as in the other scale. Table II shows the sieve openings for the closer classification where the ratio is $\sqrt[4]{2}$.

TABLE II

RATIO $\sqrt[4]{2}$ or 1.189

Opening (Ratio $\sqrt[4]{2} = 1.189$) In.	Mm.	Mesh	Diam. of wire, in.
0.0082	0.208	65	0.0072
0.0069	0.175	80	0.0056
0.0058	0.147	100	0.0042
0.0049	0.124	115	0.0038
0.0041	0.104	150	0.0026
0.0035	0.088	170	0.0024
0.0029	0.074	200	0.0021

Not only do the screen scale sieves divide a product in much better proportion than a sieve series without any relationship between the open-

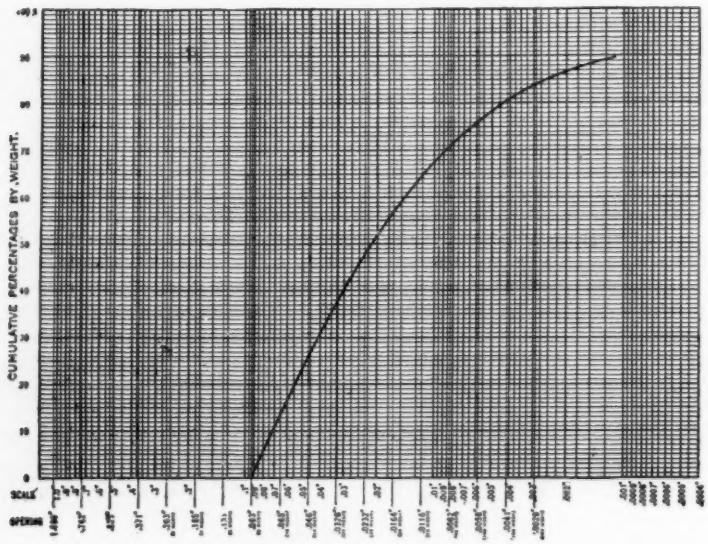

FIG. 5.—Cumulative logarithmic plot.

ings, but the results of the screen analysis can be represented by a plotted curve to much better advantage.

There are many advantages in the graphic method of illustrating the data obtained in a screen analysis. Plotted curves of the crushings by different methods or from two competing machines, for instance, express the difference in a more striking and concise manner than do the tabulated data. Of the several methods of plotting these curves, the cumulative direct plot and cumulative logarithmic plot are the two most valuable and generally used.

The curves by either method are plotted by marking the cumulative percentages of the material which remain on the sieves as ordinates on

vertical lines drawn from the several corresponding openings on the horizontal scale of the diagram.

After drawing in the curve, the percentages remaining on any set of openings other than those of the testing sieves used can be found by interpolation and in this way the redistribution of the same material by any assumed set of openings can be determined without having sieves of those openings.

By cumulative percentage is meant the total amount of the product which would remain on a testing sieve if only one sieve were used for testing the whole sample, so that to get the cumulative weight, it is necessary to add all of the material which remains on sieves coarser than the one in question to the amount remaining on that sieve. In other words, each point on a cumulative plot represents the total material that would be retained if only the one sieve represented by that particular point were used in the analysis.

Table III represents a screen analysis showing the percentages and cumulative percentages shown in the Cumulative Logarithmic Plot in Fig. 5.

TABLE III

SCREEN ANALYSIS SHOWING CUMULATIVE PERCENTAGES

SCREEN-SCALE RATIO 1.414

	Openings Mm.	Openings In.	Mesh diam. wire, in.		Sample wts., gram	Weights, per cent	Per cent cumulative wts.
Indicate the screen crushed through and also first retaining screen	26.67	1.050	...	0.149	...	...	...
	18.85	0.742	...	0.135	...	...	...
	13.33	0.525	...	0.105	...	...	...
	9.423	0.371	...	0.092	...	...	...
	6.680	0.263	3	0.070	...	...	...
	4.699	0.185	4	0.065	...	...	...
	3.327	0.131	6	0.036	...	...	...
All pass	2.362	0.093	8	0.032	...	...	...
Retained on	1.651	0.065	10	0.035	70.0	14.0	14.0
	1.168	0.046	11	0.025	60.0	12.0	26.0
	0.833	0.0328	20	0.0172	50.0	10.0	36.0
	0.589	0.0232	28	0.0125	55.0	11.0	47.0
	0.417	0.0164	35	0.0122	50.0	10.0	57.0
	0.295	0.0116	48	0.0092	35.0	7.0	64.0
	0.208	0.0082	65	0.0072	30.0	6.0	70.0
	0.147	0.0058	100	0.0042	32.5	6.5	76.5
	0.104	0.0041	150	0.0026	20.0	4.0	80.5
	0.074	0.0029	200	0.0021	17.5	3.5	84.0
Pass	0.074	0.0029	200	0.0021	80.0	16.0	
Totals					500.0	100.0	

Fig. 6 shows a cumulative direct plot of the screen analysis given in Table III. This form of direct plotting is unique, since all crushings, to whatever size, are expressed on diagrams of the same uniform dimensions and having

the same length of base line. This renders a comparison of the curves from various crushings more comprehensive than when diagrams with varying lengths of base line are used.

The vertical lines on the diagram represent any given set of sieve openings having a constant ratio of 1.414, the first left-hand vertical representing the screen opening through which the sample has all been crushed, and the last or extreme right-hand vertical, representing zero. The curves, therefore, start at the lower left-hand corner and terminate at the upper right-hand one.

To illustrate the usefulness of the plotted curve, let us take an illustration from actual practice. Given a sample of concentrator mill heads, which are the undersize of Hum-mers Electric Screens equipped with 3-mesh

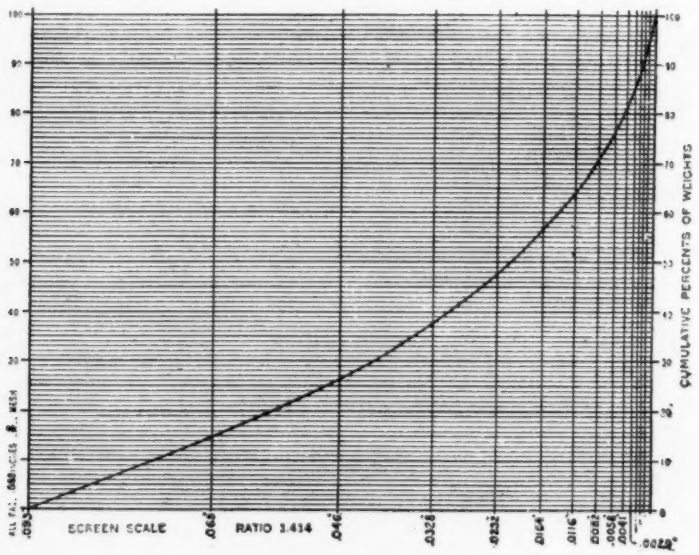

FIG. 6—Cumulative Direct Plot.

0.148 in. wire, opening 0.158 in. According to the arrangement of the mill, these mill heads pass successively through three sets of Hum-mers, the oversize of which is delivered to three sets of jigs, while the undersize of the last screen passes to tables and vanners. With the last of the three screens equipped with 12-mesh, 0.047 in. wire, opening 0.036 in., with what size of screen openings should the other two screens be equipped to divide the jig product evenly by weight between the three sets of jigs?

The screen analysis of the product passing the 3 mesh, 0.148 in. Hum-mers is shown in Table IV. It has only been carried as fine as the 0.0058 in. (100-mesh) sieve, since we are not interested in the fines which go to the tables.

TABLE IV
SCREEN ANALYSIS OF CONCENTRATION MILL HEADS
SCREEN-SCALE RATIO 1.414

	Openings Mm.	Openings In.	Mesh diam. wire, in.		Sample wts., gram	Weights, per cent	Per cent cumulative wts.
Indicate the screen crushed through and also first retaining screen	26.67	1.050	...	0.149	...	...	...
	18.85	0.742	...	0.135	...	...	...
	13.33	0.525	...	0.105	...	...	...
	9.423	0.371	...	0.092	...	...	...
	6.680	0.263	3	0.070	...	...	...
All pass	4.699	0.185	4	0.065	...	...	...
Retained on	3.327	0.131	6	0.036	253	12.65	12.65
	2.362	0.093	8	0.032	264	13.2	25.85
	1.651	0.065	10	0.035	262	13.1	38.95
	1.168	0.046	14	0.025	155	7.75	46.70
	0.833	0.0328	20	0.0172	132	6.65	53.35
	0.589	0.0232	28	0.0125	126	6.3	59.65
	0.417	0.0164	35	0.0122	94	4.7	64.35
	0.295	0.0116	48	0.0092	83	4.15	68.5
	0.208	0.0082	65	0.0072	66	3.3	71.8
	0.147	0.0058	100	0.0042	64	3.2	75.0
All pass 0.0058 in.					500	25.0	
Totals					2000	100.0	

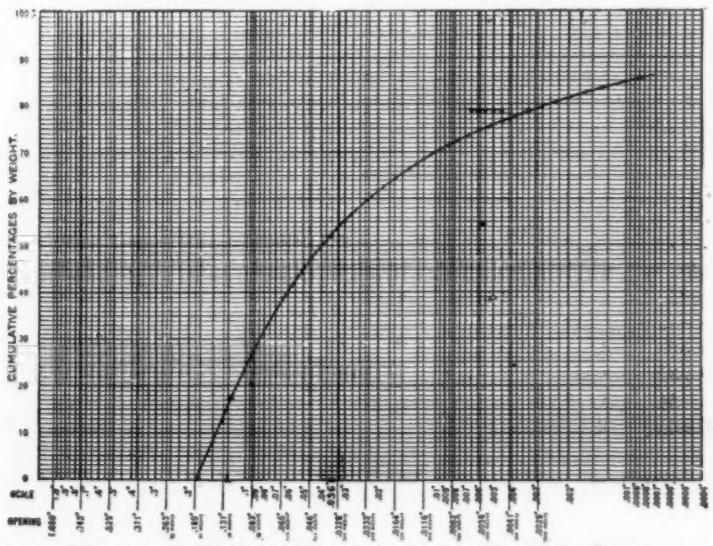

FIG. 7.—Curve showing screen analysis of concentrator mill heads.

After plotting the curve (Fig. 7), showing this screen analysis, we find that the opening 0.036 in. (the 12-mesh, 0.047 in. wire on the last screen) will retain 52.5% of the product, which is the amount to be divided equally

by weight between the three sets of jigs. One third of this amount is 17.5%. By finding the point on the curve representing 17.5% of the product, we see that this part of the material will be retained by an opening of 0.125 in.; the position of the point on the curve representing 35% of the product indicates that an opening of 0.0725 in. will retain

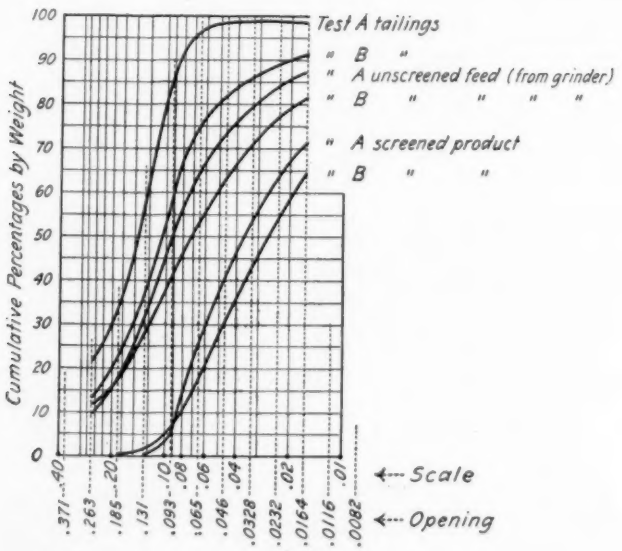

FIG. 8.

Screen scale ratio 1.414			Product being ground and separated					
Size hole	Mesh	Dia. wire	Talling Test A	Talling Test B	Unscreened feed Test A	Unscreened feed Test B	Screened product Test A	Screened product Test B
.263"	3	.070"	21.4%	13.0%	11.3%	9.8%	0.0%	.0%
.185	4	.065	11.6	9.6	6.2	7.2	.0	.1
.131	6	.036	25.8	15.6	14.9	10.3	.1	1.1
.093	8	.032	24.6	20.4	17.5	12.8	5.8	5.1
.065	10	.035	13.2	16.4	14.8	13.9	19.3	10.3
.046	14	.025	1.7	7.5	8.3	9.5	16.2	13.5
.0328	20	.0172	.4	3.5	5.6	6.3	11.2	11.9
.0232	28	.0125	.1	3.0	5.1	6.4	10.3	10.7
.0164	35	.0122	.1	2.1	4.1	5.1	8.3	11.0
Passing	35	(Finer)	1.1	8.9	12.2	18.7	28.8	36.3
Totals			100	100	100	100	100	100

that percentage of the product. Therefore, to divide the product equally on the three jigs the first screen must be covered with a cloth that will retain the 0.125 in. part of the ore, and the second screen with a cloth that will retain the 0.0725 in. part of the ore. It is then an easy matter to select the required style of cloth to produce this result.

It is easily seen how this would apply to any distribution of sizing and for any purpose.

Figure 8 shows the results obtained through screen analysis on a heavy clay products plant, in operation in Ohio. The cumulative per cent was

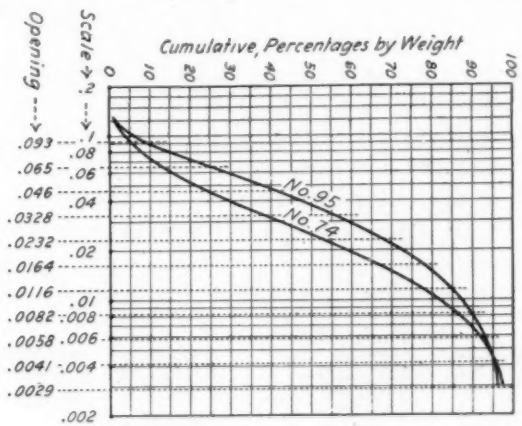

FIG. 9.

Screen scale ratio 1.1414

Indicate the screen crushed through and also first retaining screen	Opening Inches	Opening Millimeters	Mesh	Diameter wire, inches	No. 74 per cent	Cumulative per cent	No. 95 per cent	Cumulative per cent
.....	1.050	26.67	...	.149	....	....	....	....
.....	.742	18.85	...	.135	....	....	....	....
.....	.525	13.33	...	.105	....	....	....	....
.....	.371	9.423	...	.092	....	....	....	....
.....	.263	6.680	3	.070	....	....	....	....
.....	.185	4.699	4	.065	....	....	....	....
.....	.131	3.327	6	.036	.8	.8	.8	.8
.....	.093	2.362	8	.032	4.0	4.8	7.6	8.4
.....	.065	1.651	10	.035	8.3	13.1	16.8	25.2
.....	.046	1.168	14	.025	11.0	24.1	16.4	41.6
.....	.0328	.833	20	.0172	13.8	37.9	14.2	55.8
.....	.0232	.589	28	.0125	16.4	54.3	12.3	68.1
.....	.0164	.417	35	.0122	12.0	66.3	9.7	77.8
.....	.0116	.295	48	.0092	10.0	76.3	6.3	84.1
.....	.0082	.208	65	.0072	9.4	85.7	5.9	90.0
.....	.0058	.147	100	.0042	6.4	92.0	4.8	94.8
.....	.0041	.104	150	.0026	3.7	95.8	2.2	97.0
.....	.0029	.074	200	.0021	1.4	97.2	1.0	98.0
Pass.....	.0029	.074	200	.0021	2.8	100.	2.0	100.
Totals					100		100	

left out of the table, but is plotted in the cumulative logarithmic plot just above. (See Fig. 5.) The grinding unit consists of a battery of dry pans preceded by a crusher.

They found through screen analysis that the proportioning of the aggregate of the body of this product played an important part in influencing the resistance of their brick in the abrasion test. By extending the analysis so as to cover the entire operation, that is, taking samples of the fines that were being retrieved from their screens, samples of the circulating load that were going to the screen from the dry pans, and samples of the tailings being returned to the dry pan, an efficiency factor was obtained, and having learned the proportions desirable, they found that it could be gotten by making some changes in their screening equipment and holding to a given size opening in their dry pan plates.

Incidentally, by efficient screening methods, the proportions given in the analysis in Figure 8 were maintained very closely, irrespective of the varied water content in the material. The plant has been in operation a number of years and an improvement in the quality of their product

FIG. 10.

amounting to a greatly decreased loss and a rare uniformity in their rattler test have been their reward for nearly two years since going from guess work methods to pre-determined mixtures.

Figure 9 illustrates a cumulative logarithmic plot of an inefficient and subsequently efficient screening operation of the products of a dry pan. You will observe an improvement in their separation amounting to as much as 8% of the total fines retrieved on a single sieve was obtained by changing their screening equipment without changing any features of their grinding unit or abandoning the size of the particles constituting the aggregate.

Figure 10 illustrates this same analysis in volume. You will observe that the first bottle is full and represents 100% of the product from their dry pan. The bottle containing the larger proportion, 59% full, represents the retrieved fines of the 74% efficiency separation, while the other bottle which is 41% full, represents the tailings of this same operation.

It was decided that the quality of their product would be improved and higher tonnage retrieved at a lower cost if they instituted a better screening program.

The two bottles indicated as 95% separation show the result and incidentally increased the grinding capacity of this particular unit more than 20%. However, the proportioning of the aggregate of their material was the incentive for screen analysis.

The smaller tube (Fig. 11-A) shows the product of a commercial operation on feldspar ranging from 150-mesh (0.0041 in.) to 325-mesh (0.0014 in.) and finer, classified with the $\sqrt[4]{2}$ series of sieves.

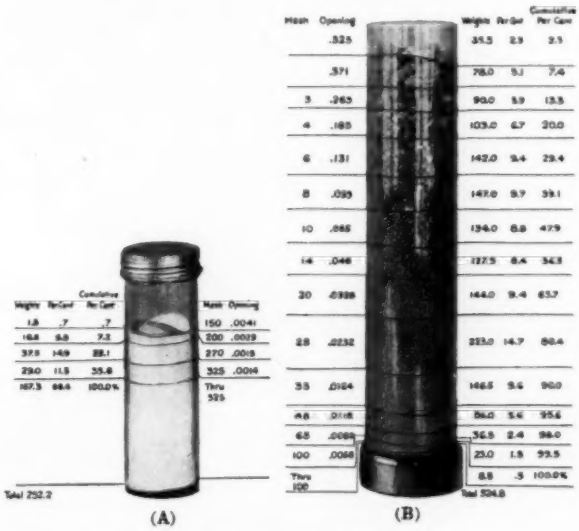

FIG. 11.—Classification of sizes.

The contents of the large tube (Fig. 11-B) represent the product of a grinding unit ranging from 0.525 in. to 0.0058 in. or 100-mesh, classified by sieve whose ratio is 1.414 or $\sqrt{2}$.

Recently in checking the efficiency of a grinding installation consisting of three different types of grinders, from which a 35-mesh product was desired, we found that two of the grinders were delivering practically the same tonnage at 10- and 14-mesh while at 35-mesh and finer, one was delivering two and a half times the tonnage of the other grinder.

After learning these facts, it was a simple matter to use the two machines in closed circuit in the order in which they were best qualified to serve and increase the tonnage to a point nearly equal the efficiency of the hitherto best producing mill.

In conclusion, to those who are familiar with the characteristics of rocks of various geological eras, to those who realize that the various components of the product undergoing mechanical disintegration is offering an equally varied resistance and leaves its evidence in size proportions; to those who would bring about certain chemical reactions by design of a predetermined temperature application; to those who would know the efficiency of their grinding and screening plants, or who would maintain a standard of quality where the size and proportion of grain wield an influence, as there is a value to the mariner in his compass, to the carpenter in his square or a designing process value to any artisan who would not trust the building of his efforts to the specifications of guess, imagination and opinion, so is there a *value* to *screen analysis* in *ceramics*.

W. S. Tyler Co.
Cleveland, Ohio

CERAMIC ABSTRACTS

Compiled by the

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Vol. 2 March, 1923 No. 3

Author Index[1] to Abstracts for March

Author	Number of abstract
Anon	2, 10, 39, 79, 90, 91, 148
Ayres, E. B	29
Bagge, P. F	146
Baillie, W. L	111
Ballo, R. and Jugovics, L	45
Barringer, L. E	22
Bied, J	144
Bingham, E. C., Bruce, H. D. and Wolbach, M. O., Jr	42
Bird, C. A	58
Bitting, A. W	100
Block, Berthold	25
Böiboul, M	62
British-Houston Co., Ltd	51
Brown, W. D. R. and Pickston, W. T	35
Catlett, C	158
Collins, E. F	17, 52
Cordenot, L. A	85
Corse, W. M	14
Craven, M. B	80
Crossley, P. B	118
d'Adrian, A. L. Duval	61, 126
Davis, H. E	133
de Mejer, E. C	94
Denk, F. J	101
Dimbleby, V., Muirhead, C. M. M. and Turner, W. E. S	109
Duckham, A. M	6, 70
Eichenberger, F	72
Elsenbast, A. S. and Jordan, W. L	73
Feldenheimer, W. and Plowman, W. W	48
Flemming, A. P. M	59
Fleming, A. G	147
Flinn, A. D	15
Frank, E	130
Frink, R. L	122
Fuha, Kitsuzo	96, 121
Fujiyama, Tsuneichi	149
Fukuoka, Daigoro	88
Fukuzawa, Seikichi, Fukuzawa, Ito, and Toyo Gyps Co	156
Good, R	132
Granger, Albert	5
Grigorovitch, K. P	55
Grün, Richard	142
Hagiwara, Kiyohiko, Morimoto, Kan-ichi, Ueda, Kiyoshi, and Hiraoka, Taitaro	95
Hallimond, A. F	41
Hatanaka, Toyoji	152
Helbig, A. B	7
Hess, H. W	113, 114, 115
Hirano, Kosuke	60
Hull, W. A	56
Igranic Electric Co., Ltd	33, 34
Ikeda, Kikunae, Isobe, Hajine and Okazawa, Tsuruji	47
Ishikawa, Giichi	36
Jeanneret, F. B	139
Jones, L. T	27, 28
Kallauner, O and Hruda, I	92
Kato, Komakichi and Kamibayashi, Chiaki	151
Kingsbury, Percy C	76
Kishi, Ichita	154
Kishimoto, Tatsujiro	20
Kohama, Hiroshi	37
Kondo, Seiji and Nakao, Masaru	89
Koreavaar, A	19
Krak, J. B	110
Kühl, H	116
Linebarger, C. E	30
Locke, F. M	125
Lösenbeck, Otto	46
Louis, Denis	68
Lowry, T. M. and McHatton, L. C	23
MacMichael, H. A	78
MacMichael, R. F	4
Mano, Nakajiro and Yanaka, Ryujiro	153
Marckworth, O. S	131
Mathews, J. A	53
Mattison, R. V	157
McDonald, J. U	124
Menzies, A. W. C. and Beebe, R	44
Metallbank und Metallurgische Ges. Akt. Ges	21
Meurer, N	135
Miki, Sachio	155
Miner, Harlan S	12
Minton, R. H	8
Montgomery, G. L	81
Morey, G. W	102
Morey, G. W. and Bowen, N. L	108
Myers, W. F	137
Nagasawa, Takeo	136
Nagasaki, Shinsaku	83
Nakamura, Kihichi	150
Nakamura, S	107
Newcomb, E. W	26

[1] The abbreviation (*C. A.*) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

Author Index to Abstracts for March (*Continued*)

Author	Number of abstracts
Nichols, Wm. H.	13
Niimura, Shintaro	82
Orton, Edward, Jr.	9
Ostwald, Wilhelm	16
Parkert, O.	117
Peacock, S.	123
Pease, G. S.	63
Platzmann	145
Plauson	49
Prevost, Pierre	138
Radley, E. G.	41
Rawlins, C. D.	1
Rebuffat, O.	71
Rees, W. J.	54
Rennerfelt, I.	64
Richmond, H. A. and MacDonald R.	74
Riddle, F. H.	86
Rideal, E. K., and Thomas, Wm.	40
Ries, H. and Bayley, W. S.	38
Rigby, T.	50
Roesch, A.	31, 32
Rohn, W.	65
Rossman, W. F.	69
Scott, W. S.	134
Shakespear, G. A.	24
Sherwin, R. S.	75
Shimazu, Genzo	120
Shinagawa, Yuichi, and Yoshizaka, Seizaburo	84
Silica Syndicate, Ltd.	119
Smith, C. D.	112
Steger, W.	57
Sullivan, E. C. and Taylor, W. C.	128
Taylor, T. S.	11
Taylor, W. C.	129
Travers, M. W.	98, 99
Treischel, C. C.	87
Trinks, W.	18
Turner, W. E. S.	97, 104
Turner, W. E. S. and Wilson, T. E.	105
Twyman, F.	103
Van Marle, M.	127
Weigel, W. M.	77
Whatmough, W. A.	106
White, C. A.	66, 67
Whitby, B. R.	159
Williams, W. D.	43
Witt, J. C.	140, 141, 143
Yashoro, Tamotsu	3
Yokoi, Ichiro	93

General and Miscellaneous

1. Chemical industry in Greece. C. D. RAWLINS. *Chem. Trade Jour.* (London), **71,** 231(1922).—The chem. indus. in Greece is making progress. There are 4 factories for the manuf. of glass and pottery with up-to-date plants. Fertilizers are made in one large factory. Sulphuric acid is also manufd. out of local pyrites. There is one factory for the manuf. of aniline dyes; soap and sulphur oil are old-established industries and turpentine oil and colophon are distilled from local pine resin. O. P. R. O.

2. Bentonite used in the de-inking of paper. ANON. *The Chem. Age,* **7,** 668 (1922).—Bentonite, the natural mineral substance, has been found to be an extremely efficient agent for de-inking old newspapers and has been described as a natural soap on account of its detergent properties. In the exptl. tests with the material on old newspapers, bentonite was used with just sufficient alkali to loosen the ink without discoloring the paper. It was found that the small particles of the mineral could be easily carried through the ordinary washing screen. O. P. R. O.

3. Report of experiments with a gas-producer. TAMOTSU YASHORO. *J. Jap. Cer. Assoc.,* **361,** 424–42(1922).—The author performed 83 expts. with a Dowson gas-producer at the Tsurumi plant of the company. The producer had a water-sealed Thwaite's ash-pit with a steam-blower. It consumed 18,700 lbs. of a Hokkaido coal, consisting of 77.8% lumps, 21.9% medium lumps and 1.2% small coal, per day. It was poked 5 times an hr.—(1) *Temp. in the producer.*—The most suitable temp. of coke-layer was 1000–1100°C. When it was cooled below 800°C, the gas was useless. (2) *Propn. of steam and air.*—The best gas was produced when they were introduced to the blower in the propn. of 75.18% air and 24.82% steam in vol. (3) *Thickness of fire-bed.*—The best results were obtained when the layers of coke and coal were 18″ to 20″ and 17″ to 20″ thick respectively. Besides, descriptions on the removal of ashes, velocity of air and steam passing through fire-bed and the pressure of steam are given. S. KONDO

4. Tests to determine the uses for clay. R. F. MACMICHAEL. *Brit. Clayworker,* **29,** 189(1920–21); *J. Soc. Glass Tech.,* **5,** 28–9.—The general phys. characteristics were

first noted. These included color, hardness, fracture, uniformity, org. matter, foreign material, behavior in crushing, pugging and forcing through dies. Plasticity was detd. by noting the amt. of water required to form a slip of standard viscosity. The clay was blunged, deflocculated to its max. viscosity with a suitable electrolyte, and dild. with H_2O to a standard viscosity. The amt. of water contained in the slip was detd. and was a measure of the plasticity. The wet-strength of the clay was tested in a machine similar in operation to the ordinary cement-testing machine. Blunging and screening through a 200-mesh sieve sepd. the clay into two portions, each of which was dried and weighed and its character noted. Chem. analysis was made as usual. Drying qualities were examd. by drying 100 g. of wet clay in briquet form at 160°F under standard conditions. A balance and shrinkage gage indicated the loss of wt. and shrinkage simultaneously. For tests on dry and fired material, bars half an in. in diam. were expressed on to a grooved board and cut into 5-in. lengths. The bars were then stamped with a sample number and notched with a 100 mm. gage and the av. wet wt. was noted. On these samples drying shrinkage, firing shrinkage, breaking wt. (transverse), warping, loss of wt., porosity, and d. were detd. The point at which a sample sagged under its own wt. on heating was taken as its refractory index. H. G. (*C. A.*)

5. The firing of ceramic products in electrically heated furnaces. ALBERT GRANGER. *Compt. rend.*, **175,** 98–100(1922).—Furnaces heated electrically by Pt wire or by granulated C, were used in lab. tests. China fired white, a ferruginous stoneware red and Sevres porcelain an amber tint, all about like products from the ordinary kiln. Hard porcelain fired gray, and had the appearance of com. porcelain fired in a too highly reducing atm. This gray color is usually explained by the occlusion of C deposited from the flame. In this case the corundum furnace, where no flame existed, was sufficiently porous for CO to penetrate, whereupon it deposits C according to the probable reaction: $2CO \longrightarrow C + CO_2$. This blackening was avoided when CO was eliminated by a moderate draft. C. C. D. (*C. A.*)

6. Some new forms of kilns. A. DUCKHAM. *Engineering*, **114,** 534–6(1922).—Two kilns, one continuous, the other tunnel, are described. The continuous kiln has 16 chambers each 19 ft. wide, 17 ft. long, 6 ft. high at the sides and 10 ft. at the middle. The chambers are in 2 rows of 8 each. There are 4 fireboxes, 2 on each side of each chamber. Fire bricks are burned to cone 13. Fuel consumption is 20–25 tons of coal per 100 tons of brick. Air leakage, chiefly through the main dampers to the chambers, interfered with draft and cast iron flap doors were put in. Artificial draft also was introduced. A new modification with central bags feeding producer gas is described. The tunnel kiln described has a fixed central heating zone and the hot gases follow a zig-zag path. A modification in annular form was devized for burning glazed ware. Excellent drawings are given. C. H. K. (*C. A.*)

7. The dangers of powdered fuel. A. B. HELBIG. *Feuerungstechnik*, **10,** 188–90 (1922).—Coal dust will not burn unless very intimately mixed with air in proper proportions. Mills for powd. coal are not dangerous, even if fed with glowing coal, or pieces of steel that produce copious sparks. Kept in large closed silos powd. coal is not dangerous, so long as these have no dead spaces where the coal is not disturbed. Great cleanliness in the plant, avoidance of dust clouds, and care in igniting coal dust flames will make this as safe as any industrial process. E. W. T. (*C. A.*)

8. Historical sketch of the pottery industry. R. H. MINTON. *The New Jersey Ceramist*, **2** [3], 179(1922).—The paper covers briefly the historical development of porcelain, both oriental and occidental. C. W. PARMELEE

9. Address at the dedication of the New Ceramics Building at Rutgers College. ED. ORTON, JR. *New Jersey Ceramist*, June, 96(1922).—A brief statement of the inception of ceram. ed. in the United States. C. W. PARMELEE

10. Samuel Wesley Stratton. ANON. *Elec. World,* **80,** 860(1922); 1 illus.—Biographical sketch. See also *Bull. Amer. Ceram. Soc.,* **1** [11], 331–32(1922).
C. G. F. (*C. A.*)

11. Stimulating research by organization. T. S. TAYLOR. *Elec. World,* **80,** 961–2(1922).—A clear and concise expression of an ideal research lab. organization.
C. G. F. (*C. A.*)

12. Grasselli Medal award (to Walter H. Fulweiler). Presentation. HARLAN S. MINER. *J. Ind. Eng. Chem.,* **14,** 1154–5(1922). **Acceptance.** *Ibid.,* 1155.
E. J. C. (*C. A.*)

13. Ernest Solvay—an appreciation. WM. H. NICHOLS. *J. Ind. Eng. Chem.,* **14,** 1156–8(1922).—An obituary. E. J. C. (*C. A.*)

14. Federal and state research agencies. W. M. CORSE. *Trans. Am. Soc. Steel Treating,* **3,** 231–8(1922).—An address. W. A. M. (*C. A.*)

15. Research for engineering societies. A. D. FLINN. *Trans. Am. Soc. Steel Treating,* **3,** 218–25(1922).—An address. W. A. M. (*C. A.*)

16. What progress has the new science of color brought? WILHELM OSTWALD. *Z. Elektrochem.,* **28,** 398–404(1922).—An address. H. J. C. (*C. A.*)

17. Electric heat, its generation, propagation and application to industrial processes. E. F. COLLINS. *Trans. Am. Electrochem. Soc.,* **42,** preprint(1922).—The development of elec. heat by passage of current through solid resistors, through liquid and through gaseous media is discussed at length, reference being made in particular to the fundamental theoretical principles. An efficient, com. elec. heating app. must be constructed with due regard to chem. reactions taking place, to the effect of mech. changes, such as expansion with heat, to phys. factors such as heat transmission and heat emissivity and to the comparative cost and operating factors. C. G. F. (*C. A.*)

18. Heat balances of blast furnace and steel plants. W. TRINKS. *Blast Furnace Steel Plant,* **10,** 451–6(1922).—Ideal heat balance charts are given for (1) an uneconomical steel plant, (2) an av. American plant, (3) an economical steam-operated plant, and (4) an ideally operated plant. Per lb. of finished steel produced plant (1) uses 2.25 lbs. of coal; plant (2), 1.5 lbs.; plant (3), 1.065 lbs.; plant (4) 0.89 lbs.
L. J. (*C. A.*)

19. The theory of gas producers and its application to blast furnace operations. A. KOREAVAAR. *Chimie et industrie,* **8,** 12–25(1922).—K. puts forward a theory of gas producers based partly on that of H. LeChatelier ("Le Chauffage Industriel"), partly on that of J. E. Johnson (Principles, Operation and Products of the Blast Furnace), and partly on Langmuir's theory of the reaction of a heterogeneous system (*C. A.*, **10,** 3007). He investigates the influence of the activity, size and porosity of the C and of the quantity and temp. of the air on the vol. and temp. of the zone of combustion. He applies his findings to that portion of the blast furnace which is in the immediate neighborhood of the tuyeres, and concludes that (1) the more oxidizable the coke the lower the consumption for a given temp.; (2) for a given temp. hot air requires a lower coke consumption than cold air; (3) "low coke consumption goes hand in hand with low wind," proper temp. being obtained by suitable quality of the coke and preheating of the air; (4) heating the air above a certain "critical temp." (about 800°) does not appreciably increase the temp. of the zone of combustion, and hence does not appreciably cut down coke consumption; (5) by increasing the amt. of air above a certain "critical value," the temp. is not increased, but the vol. of the zone of combustion can be increased as much as desired, within the limits of possibility. A. P.-C. (*C. A.*)

PATENTS

20. Roofing-tile kiln. TATSUJIRO KISHIMOTO. Japan 43,050, July 11, 1922. A roofing-tile kiln has three chambers which are arranged so as to form an arch. In

other words, the middle chamber is built over the passage between the other two. The waste-gases of the lower chambers are made to pass through the middle one.

S. KONDO

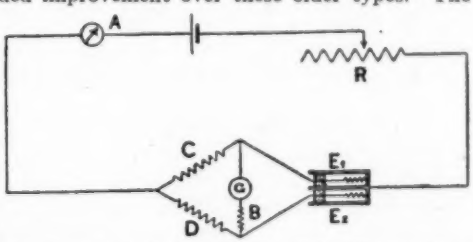
21. Electric dust precipitation. METALLBANK UND METALLURGISCHE GES. AKT.-GES. Brit. 177,117, Sept. 23, 1921. Furnace gases are cooled to the dew point or below, whereby they are de-ionized, and are heated again in such a way as to prevent ionization by flames, etc. The gases then enter an elec. precipitator, in which dry deposits are thus obtained. (*C. A.*)

22. Electrical insulating composition. L. E. BARRINGER. U. S. 1,423,985, July 25. An insulating compn. which is resistant to heat is formed of shellac, NH_4OH and Na silicate with coloring and filling materials. (*C. A.*)

Apparatus and Instruments

23. The grading of powders by elutriation. T. M. LOWRY AND L. C. MCHATTON. *J. Oil Colour Chem. Assoc.*, **5**, 82–91(1922).—Grading of powders such as Portland cements and paint pigments by sieving air and H_2O-flotation, etc. is reviewed. The most satisfactory elutriator is the single vessel form described by Boswell (Brit. Resources of Sands and Rocks Used in Glassmaking, 2nd ed. (1918)). With this app., barytes and quartz powders were fractionated by a vertical flow of H_2O at 4, 5, 6, 7, and 8 mm. per sec., and the particle diams. detd. microscopically. The grading is much more exact in a tube of 27 mm. diam. than in one of 13 mm. diam. because of the friction on the walls and the resultant gradient in the velocity of flow. The crit. diam. of the particles is about 5% greater in the narrow than in the wide tube. The crit. particle diam. decreases with rising temp. of the H_2O. The relation between diam. of grains and velocity of flow is not a linear function, nor does it obey the square or square root law as commonly stated. Under identical conditions, the diams. are 1.42 times as great for quartz as for barytes, so that sectional areas are as 2.0 : 1. This ratio is identical with the gravitational forces on the immersed particles. The lifting power of the H_2O is therefore proportional to the area of the particle. Results are tabulated and plotted. Illus. with photomicrographs. Discussion. F. A. W. (*C. A.*)

24. Electrical carbon dioxide recorders. G. A. SHAKESPEAR. *Electrician*, **89**, 543 (1922).—Most of the instruments now available for measuring CO_2 in flue gases depend on one or several chem. reactions; the chemicals have to be replenished from time to time and besides there is the disadvantage of delicate glassware in the construction. The new recorder described is a decided improvement over these older types. The underlying principle of the new type: Two identical spirals of Pt wire are enclosed in two sep. cells, E_1 and E_2 (see fig.) in a metal block. Each of the spirals is connected to one arm of a Wheatstone bridge, the other 2 arms, *C* and *D*, being of manganin. Current flowing through the bridge heats the Pt spirals and causes them to lose heat to the walls of the cells. If the compn. of the gas of one cell is different from that of the other, the thermal cond. and hence the cooling rate will be different, giving rise to difference in temp. of the 2 wires. The difference in temp. will cause a deflection of the galvanometer, the greater the temp. difference the greater the deflection. One cell is filled with air and sealed and the other is exposed to the flue gas. A filter of glass wool and Fe borings is placed ahead of the open cell to protect the Pt. Further details are given. C. G. F. (*C. A.*)



25. The sieve centrifugal. BERTHOLD BLOCK. *Chem. App.*, **9**, 88–91, 117–20, 141–4, 153–6, 169–71, 177–9, 189–92(1922).—A discussion, with 58 cuts, of the construction of centrifugals with mech. discharge, semi-automatic centrifugals, continuously operating centrifugals, of the proper weave of the top sieve for materials of different grain, of the proper construction of the sieve backing to prevent clogging, of the proper clothing, with references to the literature and Ger. patents. J. H. M. (*C. A.*)

26. A new type of automatic temperature regulator and its application to heat-treating furnaces. R. W. NEWCOMB. *Trans. Am. Soc. Steel Treating*, **3**, 28–102 (1922).—The regulator consists of 4 parts: the frame and bed plate, a $^1/_{12}$ h. p. motor with worm and worm gear speed reductions, an escapement or ratchet mechanism and a contractor. One sprocket, mounted on a ratchet wheel spindle, is connected by a sprocket chain to another sprocket wheel attached to the valve or other appliance to be regulated. When either one of the solenoids is energized one of the pawls of the escapement mechanism engages with the ratchet wheel and moves it in one direction or the other depending upon which pawl is engaged. The movement of the ratchet wheel depends upon the setting of the wrist pin at the cam. Proper selection of the sprockets can be made to correspond to open and closed valve positions. W. A. M. (*C. A.*)

27. New rotary mercury pump. L. T. JONES. *Phys. Rev.*, **18**, 332(1921).—This pump is a liquid piston pump with Hg level remaining const. The rotation of an iron drum forces air from the high vacuum side along the axis of the drum to the low vacuum side where it is removed by an auxiliary pump capable of producing a vacuum of about 1 mm. The general performance is of the same order as that of the Gaede pump. D. MACR. (*C. A.*)

28. Simplest mercury vapor pump. L. T. JONES. *Phys. Rev.*, **18**, 332(1921).—A bulb contg. about 25 cc. of Hg is heated by a Bunsen burner and the vapor rises through a nozzle into a water jacketed chamber. The air intake is situated a little below the end of the nozzle but above the lower end of the water jacket. A fore pump capable of producing a vacuum of about 0.001 mm. removes the air from the top. Pyrex glass is used. D. MACR. (*C. A.*)

PATENTS

29. Apparatus for drying thin plates or other clay articles. E. B. AYRES. U. S. 1,429,997, Sept. 26. (*C. A.*)

30. Hydrometer. C. E. LINEBARGER. U. S. 1,424,730, Aug. 1. Homogeneous substances of different densities are enclosed in the hydrometer tube to indicate different sp. grs. even if these substances become broken within the tube. (*C. A.*)

31. Apparatus for controlling heating of vulcanizers or other apparatus. A. ROESCH. U. S. 1,430,852, Oct. 3. (*C. A.*)

32. Apparatus for controlling humidity of air. A. ROESCH. U. S. 1,430,853, Oct. 3. (*C. A.*)

33. Calorimeters. IGRANIC ELECTRIC CO., LTD. Brit. 183,408, April 7, 1921. In a continuous-flow gas calorimeter, the burner and associated parts are so constructed that the stream of fluid which absorbs the heat of combustion is made to flow after such heat absorption in heat-exchanging relation with the same stream before or during the absorption of heat. Further, the products of combustion are made to flow in heat-exchanging relation with the combustible mixt. so as to preheat the latter. (*C. A.*)

34. Calorimeters. IGRANIC ELECTRIC CO., LTD. Brit. 183,409, April 7, 1921. In a continuous-flow gas calorimeter in which resistance thermometers are subjected to the initial and final temps. of a fluid which absorbs the heat of combustion, the thermometers are so constructed that their temp. resistance coeffs. vary in such a way that a const. relation between their resistances is maintained for a given calorific value of the gas, irrespective of the actual temp. level at which the test is carried out. The invention is

described in connection with a calorimeter of the kind described in 153,817 (*C. A.* **15,** 964), each of the thermometers contg., *e. g.*, Ni and Cu in such proportions that the desired result is obtained despite variations in the sp. heat of the heat-absorbing air and in the vapor content of the test gas, caused by variations in the temp. of the water tank contg. the wet meters supplying the gas, etc. (*C. A.*)

35. Gas-analyzing apparatus. W. D. R. BROWN AND W. T. PICKSTON. U. S. 1,422,080, July 11. The app. is adapted for automatic and continuous analysis of flue and other gases. It comprizes initial and residual gas-measuring chambers with connections such that withdrawal of the sealing liquid from the initial gas-measuring chamber by a vacuum serves to unseal the exit of the residual gas-measuring chamber. (*C. A.*)

36. Continuous centrifugal separator. GIICHI ISHIKAWA. Japan 39,669, Aug. 23, 1921. A conical cage is used as a revolving separator, the narrow part being the top. Solid sepd. from the liquid is continuously collected in the bottom. (*C. A.*)

37. Centrifugal water separator. HIROSHI KOHAMA. Japan 39,671, Aug. 23, 1921. The gearing of the revolving axis and gear wheel is easily detached, so the latter is quickly stopped. (*C. A.*)

Chemistry, Physics and Geology

38. High grade clays of the eastern United States. (With notes on some Western Clays.) H. RIES AND W. S. BAYLEY. U. S. Geological Survey, *Bull.* **708** (1922).—A survey of the worked deposits of the high grade clays, such as kaolins, ball clays, and some of the refractory bond clays. The requirements of clays for porcelain, glass house refractories, abrasives, paints, paper, linoleum, etc. are discussed. The rept. gives detailed information on the occurrence and properties of the clays found in the several sections of the U. S., and describes the methods of mining, prepn. of the clays, and information as to the size and nature of deposit, at the individual mines now producing high grade clays for the ceram. indus. This rept. of 300 pages should be of particular interest to those using Amer. clays or contemplating the substitution of these clays for those imported from Europe. R. R. DANIELSON

39. Copiapite. ANON. *Min. Jour.*, **135,** 852(1921).—A large deposit of copiapite (a hydrated basic sulphate of iron, rarely met with) has been located in the northeast of S. Australia. It appears to have resulted from the oxidation of marcasite, and occurs as a lode in blue slate. On ignition, the yellow copiapite yields a rich Venetian red, and a company has been formed to open up the deposit as a source of pigments and sulphur. O. P. R. O.

40. Adsorption and catalysis in fuller's earth. E. K. RIDEAL AND WM. THOMAS. *J. Chem. Soc.*, **121,** 2119–24(1922).—Fuller's earths from Surrey, Somerset and Florida are not equally efficient in the *bleaching of edible oils*. The relations between the adsorptive and catalytic properties of these earths were examd. to obtain an explanation. The sp. surfaces were detd. to be in the ratios of 2.35, 2.13 and 1, resp. The adsorptive powers for methylene blue were in the ratios of 2.54, 2.18 and 1. The catalytic actions on H_2O_2, as measured by the reaction velocity coeffs., were 2.31, 0.58 and 2.51. Color bleaching may consist of both adsorptive and catalytic processes. The iron content of the 3 earths was possibly the governing factor in the catalysis. H. C. P. (*C. A.*)

41. Glauconite from the green sand near Lewes, Sussex; the constitution of glauconite. A. F. HALLIMOND. **Chemical analysis.** E. G. RADLEY. *Mineralog. Mag.*, **19,** 330–3(1922).—The grains, sepd. by sieving, had mean n = 1.62 and sp. gr. = 2.70. Analysis gave: SiO_2 48.12; Al_2O_3 9.16; Fe_2O_3 19.10; FeO 3.47; CaO 0.76; MgO 2.36; K_2O 7.08; Na_2O 0.22; H_2O (105°) 4.78; H_2O>105° 5.28%. In order to det. the constitution of the mineral many analyses were recalcd. in mol. proportions.

The proportion of alkalies was found to be quite const. and no evidence of the substitution of these by H_2O or by the magnesia group was detected. There is considerable replacement of the K_2O by Na_2O. In the groups R_2O_3 and RO the mol. proportions are not constant and indicate no relationship to the silica and alkalies. If the (Fe, Mg)O and (Fe, Al)$_2O_3$ are considered as mutually replaceable, the ratios obtained lead to the formula, $R_2O.4(R_2O_3, RO).10SiO_2.nH_2O$, the ratio of bases to silica being 1:2.

W. F. H. (*C. A.*)

42. The plastometer as an instrument for process control. E. C. BINGHAM, H. D. BRUCE AND M. O. WOLBACH, JR. *J. Ind. Eng. Chem.*, **14,** 1014–5(1922).—Amorphous materials often lack definite characteristics, melting point, soly., and fluidity. The authors suggest the use of (1) the yield value, (2) the mobility, (3) the concn. of zero mobility—connected with the pore space, (4) the concn. of zero yield value—connected with particle size, and (5) the temp. at which the yield value becomes zero—analogous to the melting point. The authors also distinguish between plastic and pseudo-plastic materials. E. C. B. (*C. A.*)

43. Light metal alloys for pistons. W. D. WILLIAMS. *Raw Material*, **5,** 259–66 (1922).—The disadvantages and advantages of *Al alloys* over steel and cast Fe are discussed. The difficulties encountered in the manuf. of Al alloys and their subsequent treatment for use as pistons, together with a discussion as to how to overcome these difficulties, are considered. Al alloys are also used in the manuf. of cylinders for power cars. The prospects for the new Mg alloys, which in many cases are preferred to the Al alloys, depends mainly on the soln. of the question of cost and of production in sufficient quantities. V. O. H. (*C. A.*)

44. The forms of gas and liquid cavities in gels, and their interpretation by surface compression. A. W. C. MENZIES AND R. BEEBE. *Science*, **55,** 75–6(1922).—With gelatin and silica gels in air-satd. media, controllable *bubbles* are produced by rise of temp. and reduction of air pressure. The phenomena permit of an interpretation from the point of view of *surface compression* rather than of surface tension. In a gel, space occupied by a bubble which has been caused to diminish becomes filled with liquid. This phenomenon has not before been described. These cavities are of two forms. (1) Derived from gas cavities of oblate spheroidal form they take the shape of bivalve molluscs, the "shells" being shaped like segments of spheres, bowls, etc. While the sphere is the stable form enveloped by a membrane under surface tension, this is not the case if the membrane is under surface compression. The membrane is thus thrust out at surfaces of smallest radius of curvature, giving rise to the forms observed. (2) Derived from cavities of prolate spheroidal form they take the form of a solid of three lunes, having one axis of triad symmetry perpendicular to one plane of symmetry. The three segments of the surface are of "orange peel" shape. "It is believed that the forms here described and interpreted are unique in organic nature." H. W. B. (*C. A.*)

45. The theory of the formation of dolomite. R. BALLO AND L. JUGOVICS. *Földtani Közlöny*, **45,** 221–33 (Hungarian), 286–92 (French) (1915); *Mineralog. Abstracts*, **1,** 317.—Expts. were made on the action of H_2S, NH_4, and SiO_2 (as an alk. silicate soln.) on the system $CaCl_2 + MgCl_2 + Na_2CO_3 + NaCl + H_2O$ at 18–20° and normal pressure. These show that under those conditions dolomite is not formed. Crystals of artificial *nesquehonite* are described with $n = 1.4745 - 1.557$. E. F. H. (*C. A.*)

46. An investigation of the electrical properties of silica acid sols. OTTO LÖSENBECK. *Kolloidchem. Beihefte*, **16,** 27–46(1922).—The addn. of silicic acid sol decreased the cond. of solns. of HCl, at first rapidly and then always less, according to an *e*-function. The curve finally approached asymptotically the limiting value. The migration velocity of SiO_2 particles was detd. experimentally and substituted in Smoluchowski's equation in order to calc. the contact potential. This equation (cf. *Krak. Anz*, **1903,** 182) is $U =$

$Vk/4\pi\eta$, in which U is the migration velocity for a field strength of 1 E. S. unit, V is the p. d. of the double layer in E. S. units, k is the dielec. const. for H_2O and η is the viscosity of H_2O in C. G. S. units. As shown by cataphoresis, the SiO_2 particles were negatively charged. This negative charge decreased with each addn. of HCl to zero at the isoelec. point and finally the particles assumed a positive charge greater than the negative charge for the acid-free sol. The behavior of the SiO_2 particles was not uniform. Measurements for different concns. of the same sol showed the contact potential to be dependent on the concn. To explain the observed facts the suggestion is made that the SiO_2 particles absorb the HCl like a sponge. H. M. McL. (*C. A.*)

PATENTS

47. Process of giving form to fuller's earth. KIKUNAE IKEDA, HAJIME ISOBE AND TSURUJI OKAZAWA. Japan 42,368, April 20 (1922). Short rough-surfaced cords or threads are made by pressing a mass which has been prepared by kneading a mixture of fuller's earth or Florida earth and 80–110% of water through a small opening. They are then heated at 150–600°C. These cords or threads are used for drying air.

S. KONDO

48. Treating clay. W. FELDENHEIMER AND W. W. PLOWMAN. Brit. 184,271, May 9, 1921. A process for the treatment of clay comprizes deflocculation of the clay in an aq. medium by means of a dil. soln. of HPO_3 or the metaphosphate of an alkali either alone or in conjunction with an alkali such as Na_2CO_3. The proportion of deflocculator may be varied according to the hardness of the H_2O used. The clay may be subsequently recovered from its suspension in any desired manner. When flocculation is adopted an aq. soln. of alum, or $NaHCO_3$ may be used as a flocculator, in the manner described in 121,191. Cf. *Ceram. Abs.*, **1** [10], 251. (*C. A.*)

49. Refining clay. PLAUSON'S (PARENT CO.), LTD. Brit. 184,880, May 21, 1921. Pure kaolin is prepd. by sepn. of SiO_2 and other silicates by intensive mechanical disintegration at a peripheral speed of over 1000 m. per min., preferably in the colloid mill described in 155,836, with H_2O and with or without a dispersator, the kaolin being selectively colloidalized. Suitable dispersators are water-glass, tanning agents, humus and humic acids or their compds., saponin and other soap-like froth-forming substances or sol. silicates, aluminates, ferrocyanides, thiocyanates and borates. The resulting dispersion may be concd. by ultra-filter presses. The colloidal clay may be used in the manuf. of colloidal inks, as a filler in rubber mixings, etc. Cf. 3592, **1880.** (*C. A.*)

50. Drying clay. T. RIGBY. Brit. 183,535, April 16, 1921. Pastes of china or like clay such as are dug from the ordinary settling pits are dried by being spread as films upon heated surfaces in app. such as that described in 149,055, in which the surfaces are heated by the vapors evolved from the film, after compression, or in the multiple-effect app. described in 180,963, and 181,035. A suitable construction is specified. (*C. A.*)

51. Porcelain. BRITISH-HOUSTON CO., LTD. Brit. 184,090, Sept. 27, 1921. A ceramic material particularly suitable for elec. insulation is obtained by firing a mixt. contg. 5–35% of beryl in addition to the usual ingredients, such as clay, silica, and feldspar. (*C. A.*)

Refractories and Furnaces

52. Materials for furnaces and ovens. E. F. COLLINS. *Chem. and Met. Eng.*, **28,** 79(1923).—An abstract of a paper by E. F. Collins, on "Electric Heat, Its Generation and Application to Industrial Processes," presented before the Amer. Electrochem. Soc. Charts and tables are reproduced showing the limitations of various metals and ceramic products for furnaces, particularly elec. heated equipment. One chart shows the thermal resistance of heat insulators, refractories, and heat conductors.

R. R. DANIELSON

53. Electric furnaces produce quality steel. J. A. MATHEWS. *Elec. World*, **80**, 1086, 1088, 1091(1922); 6 illus.—The reasons for the world-wide expansion of elec. steel making are (1) cheapening of wholesale power rates, (2) extreme flexibility and adaptability of furnace, and (3) superior quality of product. For installed elec. furnace capacity, Italy now ranks ahead of Germany, England and France, and second only to the U. S. C. G. F. (*C. A.*)

54. Refractories for electric furnaces. W. J. REES. *Foundry Trade J.*, **23**, 66–7 (1921); *J. Inst. Metals*, **27**, 525.—The desirable properties of a dependable refractory for an elec. furnace lining are: (1) high m. p. and strength at high temp.; (2) uniformity of vol.; (3) high resistance to abrupt temp. changes; (4) high resistance to slag and metal attack; (5) high resistance to abrasion of hot gases; (6) low elec. cond.; (7) low sp. heat. H. G. (*C. A.*)

55. Electric furnaces for the melting of steel. K. P. GRIGOROVITCH. *Rev. metal.*, **19**, Abs. Sec., 412–13(1922).—A review of the resistance (Hoskins), the induction (Rodenhauser), and the arc (Rennerfeld and Heroult) types of elec. furnaces and their industrial applications. W. A. MUDGE (*C. A.*)

56. A study of refractories. W. A. HULL. *The Ceramist*, **2** [3], 205(1922).—General discussion of the properties, uses and a résumé of the work which has been done by the Bureau of Standards on refractory clays and refractories. The author concludes that no important advance has been made in the writing of specifications for refractories since 1911. C. W. PARMELEE

57. Determination of the softening temperature of refractory materials under load. W. STEGER. *Ber. deuts. keram. Ges.*, **3**, 1–4(1922)—The test-piece, in the form of a small cylinder, is supported on a refractory cylinder of electrode C, 6 cm. diam., and heated in a vertical cylindrical elec. resistance furnace 8 cm. diam., internally, with an e. m. f. of 100–120 v. A second (hollow) C cylinder stands on the test-piece and is provided at its upper end with a plate to which the pressure from a scale-pan carrying weights of 20–100 kg. is transmitted through a simple system of levers. The small movement of the last lever in the series is marked on a rotating drum by means of a light index, about 1 m. in length, which magnifies it 20 times. The hollow C cylinder enables the top of the test-piece to be inspected and its temp. to be measured by an optical pyrometer or a thermoelectric couple. J. S. C. I.

58. Electric furnace melting. C. A. BIRD. *Chem. Met. Eng.*, **26**, 870–1(1922).—Advance in elec. furnace applications might be hastened by attention to progress in refractories, elimination of inherently poor designs, and by seeing that competent operators are in charge of all furnaces supplied. L. J.

59. Some developments in insulating materials and processes in Great Britain. A. P. M. FLEMING. *India Rubber J.*, **64**, 641–4(1922).—Life tests of insulating materials under lab. conditions have heretofore given results not conforming well with results under practical service conditions over extensive periods. New procedures are suggested in 2 directions: (1) the use of higher temp. limits whenever safe and (2) a comparison of machine performance on a basis of temp. rise in place of a basis of total temp. as recommended by the International Electrotech. Commission. Particulars are given of the facilities established for research, with a discussion of important developments in insulating materials and processes used in various types of elec. app., with special reference to thermal considerations. C. C. D. (*C. A.*)

60. Report on the Manchurian magnesite. KOSUKE HIRANO. *J. Jap. Cer. Assoc.*, **361**, 414–23(1922).—Color, appearance, sp. gr., chem. compn. and burning behaviors of 102 specimens of magnesites which were collected from all mine-lots possessed by the South-Manchurian R. R. Co. except the Mt. Kamba and the Mt. Gyushin whose magnesites were reported by the author in the April of 1919, are described in

details. The range of sp. gr. is 2.76–3.01. They have following compns.: 0.20–30.28% silica, 0–1.80% alumina, 0.18–4.37% ferric oxide, 0–24.12% lime, 16.32–47.02% magnesia and 36.20–51.78% loss on ignition. S. KONDO

PATENTS

61. Fused zirconium oxide articles. A. L. DUVAL D'ADRIAN. U. S. 1,430,724, Oct. 3. ZrO_2 is finely ground, mixed with a binder such as starch or molasses and molded into tubes, blocks, crucibles or other articles, heated to dull redness between C electrodes and then heated by resistance to above 2500° to fuse the particles together. (*C. A.*)

62. Crucibles. M. BOÏBOUL. Brit. 179,928, May 5, 1922. Addition to 165,051. Crucibles for fusing refractory minerals are composed of a mixt. of the oxides of Zr, Y, Th and Er, suitable proportions being Zr oxide 60–80%, Y oxide 13–17%. Th oxide up to 10%, and Er oxide 5–20%. The Th oxide may be omitted. Rare earths, such as Ce oxide, may be added to the foregoing ingredients in proportions up to 20%. Ce oxide or Be oxide may be substituted for the Er oxide. (*C. A.*)

63. Refractory oxychloride cement. G. S. PEASE. U. S. 1,429,451, Sept. 19. A fire-resistant compn. adapted for molding into slabs is formed of a cellular mass of oxychloride cement the cells of which are filled with charred cork or other poor conductor of heat. (*C. A.*)

64. Electric furnace adapted for heating crucibles for metal or ceramic articles. I. RENNERFELT. U. S. 1,431,424, Oct. 10. The furnace has a central hearth on which a mass of comminuted graphite is placed and a ring-shaped hearth adapted for rotation about the central hearth. An electrode projects downward from the furnace roof into close proximity to the material on the central hearth. Cf. *Ceram. Abs.*, **2** [2], 20(1923). (*C. A.*)

65. Electric induction furnace for heat-treating or melting metals. W. ROHN. U. S. 1,431,686, Oct. 10. (*C. A.*)

66. Refractory composition. C. A. WHITE. Can. 225,123, Oct. 24, 1922. A non-recrystd. refractory material contains SiC, cryst. graphite and a carbonizing binder. A flux such as borax or sand and borax may be used to form a protective coating around the particles of the composition. (*C. A.*)

67. Refractory composition. C. A. WHITE. Can. 225,124, Oct. 24, 1922. A refractory material contains a chemically inert refractory material, cryst. graphite and a carbonizing binder such as tar or pitch. A flux such as borax or sand and borax may also be used to form a protective coating for the particles of the material. (*C. A.*)

68. Refractories. DENIS LOUIS. Can. 225,725, Nov. 7, 1922. A porous refractory material contains 30 parts of pure rich refractory earth contg. 70–80% sand, 30 parts MgO, 25 parts light earth contg. 80% sand and 5 parts sawdust. (*C. A.*)

69. Refractory material for zinc retorts. W. F. ROSSMAN. U. S. 1,424,120, July 25. A refractory material for manuf. of retorts is formed of plastic clay, finely pulverized SiO_2 and ground grog about equal in amt. to the SiO_2. (*C. A.*)

70. Gas-fired pottery kiln. A. M. DUCKHAM. U. S. 1,423,408, July 18. (*C. A.*)

71. Silica brick. O. REBUFFAT. U. S. 1,420,284, June 20. Silica brick of very nearly const. vol. and of a d. of 2.27–2.30 is prepd. by adding a phosphate, *e. g.*, Ca phosphate, contg. P_2O_5 to the amt. of 0.45% of the SiO_2 used, and heating to 1300–1350° for 8 hrs. to transform quartz into allotropic forms of SiO_2 of lower d. (*C. A.*)

72. Electrical resistance material. F. EICHENBERGER. U. S. 1,420,980, June 27. A paste is formed of finely divided Si carbide, $CaCO_3$, Fe oxide and graphite, molded and embedded in sand and burned out of contact with air. (*C. A.*)

73. Insulating cement. A. S. ELSENBAST and W. L. JORDAN. U. S. 1,421,192, June 27. A heat insulating cement adapted for covering walls is formed of diatomaceous earth 80, clay 10 and starch 10%. (*C. A.*)

Abrasives

74. Artificial corundum. H. A. RICHMOND and R. MACDONALD. Can. 220,855, July 11, 1922. An abrasive material contg. less than 0.6% Ti, 0.5–2% SiO_2 and 0.3–2% FeO is produced by melting impure Al_2O_3 substantially free from TiO_2 in the presence of Fe and reducing part of the SiO_2 and FeO without materially reducing the TiO_2, then allowing the mass to cool slowly. See *Ceram. Abs.*, **1** [10], 255(1922).

75. Alumina from low-grade bauxite or clays. R. S. SHERWIN. U. S. 1,422,004, July 4. A sintered unfused alumina, silica-lime-soda mixt. obtained from bauxite or clay, lime and Na_2CO_3, NaOH or NaCl is leached to dissolve Na aluminate; this soln. is heated under pressure to ppt. SiO_2 and alumina is recovered from it. (*C. A.*)

Stoneware, Whiteware and Porcelain

76. The unique development of modern chemical stoneware. PERCY C. KINGSBURY. *Chem. and Met. Eng.*, **27**, 1226(1922).—An acct. of the progress made during recent years in the manuf. and use of chem. stoneware. The type of clay, its prepn., and treatment of the ware during manuf. are described. The phys. and chem. properties of this type of ware are given. The writer discusses the extending uses and the probable future of this interesting and useful product. R. R. DANIELSON

77. The white clay industry in the vicinity of Langley, S. C. W. M. WEIGEL. U. S. Bureau of Mines, Serial No. 2382. The methods of mining and preparing white clays for market in this vicinity are described. Analyses of representative clays (sedimentary kaolins) are given. The clays are well adapted for use in paper stock, for which they are mainly used, and in pottery and china ware, without washing. R. R. D.

78. Pottery making in the Blue Nile. H. A. MACMICHAEL. *Sudan Notes and Records*, April–July(1922).—The manuf. of vessels which he describes are the "Burma" or pots for carrying and storing water; and the water-jars used for the "Sagias" or water-wheels. The implements used are a roughly smoothed lump of stone the size and shape of a penny bun, and an oblong, slightly concave, river shell, which, if unprocurable, can be replaced by a fragment of dry water-melon husk. With these the lump of clay is kneaded with donkey's dung; is beaten into shape, and smoothed. The industry of making the "Sagia" jars is not originally found in Sudan; but is rather Nubian and Riverian. O. P. R. O.

79. Standardization of filter presses. ANON. *J. Soc. Chem. Ind.*, **41**, 210–11R (1922).—Revision of the preliminary report of the joint committee of the Brit. Chem. Manufacturers and Chem. Plant Manufacturers Assocs. A standard design of 48 in. chamber press and 48 in. plate and frame press has been added, with feed in an external central top lug, and wash outlet cocks on upper corners. Dimensions of rubber joint rings (grommets) and grooves are standardized. Minor changes are made in the rim of all plates, the rim of center feed channel for chamber presses, and dimensions of passages. Standard identification marks are suggested. W. L. B. (*C. A.*)

80. Note on the cause of the "splitting" of a pottery body. M. B. CRAVEN. *J. Soc. Chem. Ind.*, **41**, 329–30T(1922).—In making ring supports for incandescent gas mantles trouble was encountered in splitting or splintering off. English bodies were compared with a satisfactory Germany product. Chem. analyses were about the same. The German rings showed no large content of MgO although they were sold under the name "Magnesia." Porosities were about the same—10–13%. Sections examd. under a magnification × 30 showed the marked superiority of the German ware, fine grained, homogeneous and free from laminations or cracks, in contrast with irregular grains, imperfect cohesion and striations in the English rings. The German body analyzed SiO_2 66.25, Al_2O_3 31.93, Fe_2O_3 0.72, P_2O_5 1.03, CaO 0.03, MgO 0.70, ign. loss 0.22%, alk. very low. C. H. K. (*C. A.*)

81. Modern handling methods in the manufacture of electrical porcelain. G. L. MONTGOMERY. *Chem. Met. Eng.*, **27,** 59–62(1922).—The porcelain plant of the Square D Co., Peru, Ind. is described. The complete handling system is described. Hand lift trucks, belt conveyors and gravity conveyors are used. Cf. *Ceram. Abs.*, **2** [1, 2], 56. C. H. K. (*C. A.*)

PATENTS

82. Process of manufacturing ignition-plug and other refractory porcelains. SHINTARO NIIMURA. Japan 41,540, Jan. 27, 1922. Ignition-plugs, porcelain crucibles and evapg. dishes are formed by casting slips which have previously been kept at reduced pressure by means of a vacuum pump to drive off the air or other gases contd. in them. The slips may, at the same time, be heated or boiled, under constant stirring or not. S. KONDO

83. Process of manufacturing heat-insulating wares. SHINSAKU NAGASAKI. Japan 41,666, Feb. 6, 1922. Stoves, small portable furnaces and similar vessels are formed with a stiff-plastic body which has been prepd. by mixing suitable amounts of clay and slaked lime to powder or fine grains of coal-cinder. They are fired in a Japanese roofing-tile kiln. S. KONDO

84. Method of making wares of stones. YUICHI SHINAGAWA AND SEIZABURO YOSHIZAKA. Japan 43,361, Aug. 29, 1922. Engraved wares of stone are heated, in the access of air and flame, after they have been coated with an oil. The treatment makes their texture more distinct or changes their color, and increases their hardness. S. KONDO

85. Ceramic compositions. L. A. CORDENOT. Brit. 177,160, March 14, 1922. Grains of natural or artificial corundum, or composite artificial aluminates melted in the elec. furnace are incorporated in ceramic compns. (*C. A.*)

86. Porcelain. F. H. RIDDLE. Brit. 177,553, Sept. 23, 1920. Clay is mixed with an alk. flux and sillimanite or materials adapted to interact to form sillimanite and the mixt. is fired so as to produce sillimanite and a glassy matrix in which practically all the free silica is dissolved. The clay may be kaolin with or without an admixt. of ball clay. The flux may be previously prepd. by firing a mixt. of alk.-earth oxides, introduced as talc, magnesite, whiting, dolomite or the like, and clay, with or without flint. Alternatively these ingredients may be mixed with kaolin and alumina, which react to produce sillimanite, and the operation carried out in one stage. Final product preferably contains 60–85% of sillimanite and 1.5–3.0% of alk. earths. Examples of proportions are given. (*C. A.*)

87. Porcelain. C. C. TREISCHEL. Can. 220,737, July 11, 1922. An elec. insulating material consists of a fired mixt. of clay 219, SiO_2 35, feldspar 144 and beryl 130 parts. (*C. A.*)

Art and Design

PATENT

88. Process of under-glaze coloring. DAIGORO FUKUOKA. Japan 43,176, July 31, 1922. Numerous shots of clay or other substances are soaked in wax which has or has not been mixed with pigment, are filled in a vessel so as to embed pottery body in them. By warming the whole vessel, the wax adheres to the surface of the body. The body may then be covered with a net which has previously been soaked in wax, colored with pigment or not, and warmed again. Then the body is painted with underglaze color and fired in a kiln. S. KONDO

Heavy Clay Products

89. On the absorption-test of common brick. SEIJI KONDO AND MASARU NAKAO *J. Jap. Cer. Assoc.*, **363,** 527–51(1922).—Elaborate experiments on the methods of

testing water absorption of common bricks have been worked for the National Committee on Industrial Standards. Proposed method for absorption-test. The test bricks shall first be weighed and then dried in an air bath at a temperature of 125° to 135°C for 2 hrs. After removing from the drier they shall be reweighed at once. If the second weight closely checks the first they shall be considered dry, but if it does not check the latter they shall be replaced in the drier and dried an additional 2 hrs. If the third wt. checks the second they are considered dry. In the case of doubt the bricks should be subjected to further 2-hr. drying treatments until check wts. are obtained. After the dry wt. is obtained, the bricks shall be cooled to room temp. and laid flat in a vessel. The bricks shall then be submerged in water which is one cm. deep, and the water-level shall be kept constant for 24 hrs. Then more water shall be added to the vessel so as to immerse the bricks entirely in it, their upper surfaces being 3 cm. below the water-level. Keep it for further 24 hrs. Then the brick shall be reweighed after surplus water has quickly been wiped from their surfaces with a wet cloth which has been wrung hard. All weighings shall be read to the nearest gram. S. KONDO

90. Burning roofing tile. ANON. *Brit. Clayworker*, **30**, 279–80(1922).—Tile burned in continuous kilns of suitable design are equally as good as those fired in periodic kilns and only $^1/_3$ to $^1/_2$ of the fuel is used to fire continuous kilns as compared with periodic kilns. Firms who have used continuous kilns for roofing tile may be divided into 3 groups as follows: (1) Those who have found continuous kilns satisfactory, (2) Those who have failed to get good results, and (3) Those who get good results at times but not sufficient to satisfy them. The two last groups may be divided into those whose clay is unsuitable for use in continuous kilns and those who obtain good results except for a kiln of unsuitable design. In most cases where the continuous kiln has been properly tried and found to be a failure, the fault is due to using too short a kiln, *i. e.*, one with too few chambers. Tile are more tender than brick and must be fired slower. The following schedule is employed for burning: smoking 3 days, preheating 5 days, full fire 3 days, cooling 5 days, and setting and drawing 2 days. In order to get an output of one chamber per day, it would require 18 chambers and if an additional day is devoted to preheating and another to cooling it will require a 20 chamber kiln. A chamber 14 ft. square and 8 ft. 6 ins. high will hold 4000 bricks and about 16,000 tile. Actually much narrower chambers are used, some being only 7 ft. wide so that the normal output is only 2000 brick and 3000 tile per day. By using a kiln twice the usual length it is possible to increase the rate of fire travel in the same proportion. This is done in Bührer's kiln with excellent results. Continuous kilns of the down-draft type appear to be excellent in every way for roofing tile. They are more costly to build than the simpler continuous kilns but are under better control and provide a more uniform heat. There are a good many continuous kilns which are unsuitable for roofing tile and there are also some clays which are more difficult to fire in continuous kilns than others.

H. G. SCHURECHT

91. Brick for forges and annealing furnaces. ANON. *Brit. Clayworker*, **31**, 154–5(1922).—Brick for the sides and top should be resistant to spalling while those on the bottom should be resistant to slagging action. The most suitable brick are grog fire brick. Silica brick fail because they are not resistant to spalling while special refractories are too expensive. Since these furnaces are only heated to a bright red heat No. 2 fire brick are amply refractory. The roof and sides should be built of coarse textured porous brick and must be well burned to a constant volume. Hand-made fire brick are generally preferred to those pressed in machines as the latter are usually denser and consequently not so resistant to sudden temp. changes as the hand made brick. The hearths of furnaces are very variable in temp. which is liable to change suddenly, so that resistance to sudden temp. changes is of prime importance. Resis-

tance to abrasion from the iron to be heated and corrosion from the scale and fuel are equally important. The fire brick for the hearth should therefore be fine in texture, rather dense on the surface with a porous interior. Even for the hearth it is seldom necessary to use fire brick of high refractoriness, strength being a more important property. Machine-made fire brick are quite satisfactory for the hearths of forges as they have a close-textured surface resistant to slags, while their interior is porous. H. G. S.

92. The occurrence of vanadium in ceramic raw materials and ware and its effect upon the fusibility as well as the color and formation of scum on a pure kaolin and a brick clay. O. KALLAUNER AND I. HRUDA. *Sprech.*, **45,** 333–5, 345–9(1922).—A large number of minerals contain V in small amts. and among these are clay. Seger pointed out that KVO_3 often causes a scumming and yellow discoloration on brick clays. A study was made of the effect of V_2O_5 on the fusion of clays, on the discoloration of clays and scumming. It was found that V_2O_5 in small amts. does not affect the fusibility of kaolin but in larger amts. acts as a strong flux as is shown below:

Kaolin	100	99	95	90	80	60	40	20	0
V_2O_5	0	1	5	10	20	40	60	80	100
Fusion cone	35	34	33	32	30	15	5a	08a	675°C

The V_2O_5 causes a yellow discoloration when present in quantities as low as 0.1%. This discoloration may be partly reduced by the addn. of $BaCO_3$ or $Ba(NO_3)_2$. As low as 0.001% V_2O_5 may cause scumming in a clay. This scumming may be reduced by firing with a reducing kiln atmos. and by the addn. of Ba or Ca compds. as is shown below. All tests were made on a mixt. of 99% kaolin and 1% V_2O_5 and the amt. of sol. V_2O_5 which is given below in mgs. after the diff. treatments was used to compare the diff. treatments

	No treatment	2 equivs. 5% $BaCO_3$	2 equivs. 5% $CaCO_3$	2 equivs. 5% $PbCO_3$	2 equivs. 5% $MnCO_3$	2 equivs. 5% $BaCO_3$	1 equiv. $Ba(NO_3)_2$
Dry	0.591	.....	0.542	0.219	0.443	0.223	0.034
OXID.							
500°C	0.243	0.025	0.490	0.132	0.204	0.024	0.048
700°C	0.021	0.098	0.141	0.014	0.021	0.023	0.036
900°C	0.076	0.115	0.258	0.049	0.103	0.051	0.055
1100°C	0.095	0.080	0.063	0.022	0.084	0.013	0.058
REDUC.							
500°C	0.143	0.012	0.400	0.023	0.199	0.024	0.048
700°C	0.046	0.026	0.068	0.029	0.116	0.026	0.029
900°C	0.048	0.006	0.035	0.016	0.064	0.021	0.020
1100°C	0.078	0.069	0.060	0.009	0.017	0.016	0.066

H. G. SCHURECHT

PATENTS

93. Process of manufacturing rough-surfaced architectural pottery. ICHIRO YOKOI. Japan 43,328, Aug. 23, 1922. Green bodies made of feldspar, granite and bog iron ore are put in a sagger, leaving small spaces between them. The sagger is then filled with powder of calcined quartz. By firing it to a temp., a little below the m. p. of the body, mottled wares with rough surface are obtained. S. KONDO

94. Prevention of efflorescence on bricks, etc. E. C. DE MEJER. Brit. 177,990, March 31, 1921. A compn. applied with a brush to brick, mortar, and plaster walls to prevent efflorescence consists of a mixt. of 1 cwt. of Burgundy pitch and 9 gal. of turpentine contg. in soln. 36 oz. beeswax or other wax. Half of the turpentine is added to the melted pitch at a temp. of 290–300°F, and the remainder after cooling to 100°F, or lower. (*C. A.*)

Glass

95. Study of glass. (Report No. 3.) KIYOHIKO HAGIWARA, KAN-ICHI MORIMOTO, KIYOSHI UEDA AND TAITARO HIRAOKA. *J. Jap. Ceram. Assoc.*, **362,** 457–488(1922).—This paper is a continuation of the Report No. 1, in which the authors attributed the cause of dimness of mirrors to minute spots on the surface of glass. (1) *Exudation at high temps.*—When a piece of window-glass was heated to 350–600°C for 1–2 hours in an elec. furnace, it was covered with minute particles which increased in amt. with the time of heating. They grew rapidly at 650° and disappeared almost completely when it was heated at temps. over 800°. It was observed that their amts. diminish in repeating the process, if they are wiped out every time, and also that their growth ceases completely or nearly so after the minute particles have once been erased with a piece of wood or steel. (2) *Exudation at ordinary temps.*—Similar minute particles appear also at ordinary temp., though it requires much longer time, usually more than 3 days. They must not be confused with the products of weathering. They grow uniformly scattered, in dendritic crystals or groups, the latter two aggregates being probably caused by the atm. moisture. (3) *The nature of the exuded substance.*—The substances, exuded at ordinary or higher temps., are hygroscopic and form hydrated crystals which sustain efflorescence as days pass. Microscopic examns. of these substances before and after treating with hydrochloric acid or calcium chloride, indicate that they are mainly sodium silicate, sometimes containing sodium sulphate. (4) *Amt. of the exudation.*—The amts. of the substances, exuded from window-glass when new specimens were heated at 480–520°C in a muffle-kiln for 1, 5 and 10 days, were 0.0035%, 0.0052% and 0.0088% of glass respectively. (5) *Exudation on the surface of glass-cylinders.*—Experience in the cylinder-process of mfg. window-glass tells us that the drawn cylinder is sometimes covered with minute particles, though it happens only rarely. Some cylinders which broke in drawing have shown striped growth of the particles which is more common with window-glass made by Fourcault's or Colburn's process. Such a glass is very brittle and breaks usually in leer. The authors believe that the minute particles are exuded from glass owing to its unstable state of equilibrium. (6) *Exudation in pores.*—Some pores in glass have much exudation while others show it only after heating at a temp. over 400°. (7) *Glass-mirrors.*—Glass for good mirrors must be polished to remove the exudation baked on its surface or has to be examd. with vitroscope before it is silvered.

S. KONDO

96. Coloring glass with nickel. KITSUZO FUHA. *J. Jap. Cer. Assoc.*, **361,** 430 (1922).—Numerous batches were melted to find the coloring action of nickel and its compds. on various glasses with or without addition of oxidising or reducing agent. Conclusions are: (1) Nickel oxide gives purple to potash glasses and gloomy brown to soda glasses, though these effects become less distinct as the amount of nickel oxide increases; (2) The difference in the bivalent metal of a glass-formula does not affect the color materially except barium which has peculiar effect on the color produced by nickel oxide; (3) In boro-silicate glasses, nickel oxide produces pinkish purple; (4) Metallic nickel or nickel carbonate may be used instead of nickel oxide; (5) The presence of oxidising agent (potassium nitrate), reducing agent (potassium tartrate) or arsenious acid in batches does not affect the color given by nickel oxide.

S. KONDO

97. Glass industry. W. E. S. TURNER. *Chem. Trade Jour. & Chem. Eng.*, **71,** 707(1922).—At a recent meeting of the Soc. of Glass Tech. at Sheffield University, Prof. Turner gave a short acct. of his visit to Czecho-Slovakia to investigate the position of the glass indus. He states that the indus. on the continent has not made anything like the strides it has in Eng. The Bohemian glass industry is living largely on its traditions and machinery for mfg. scarcely exists, the work being carried on largely

by hand as it was before the War. As a result Eng. in many methods, from a technical point of view, leads the European continent. O. P. R. O.

98. Clouding of table-working glass tubing in the blowpipe flame. M. W. TRAVERS. *J. Soc. Glass Tech.*, **5,** 61–70(1921).—In articles made in the blowpipe flame from glass tubing a faint opalescent ring occasionally appears immediately adjacent to the glass actually melted. The effect was only obtained with coal gas when O was in excess, and in the oxy-hydrogen flame when S compds. were introduced. The amt. of clouding varies with the time of heating. A glass jet heated externally by a H flame and conveying a current of SO_2 clouded internally on cooling. From Nernst's equation T. calcs. the dissoc. pressure, in atms., of the gases CO_2, SO_2, and SO_3 in contact with the solid phases Na_2CO_3, Na_2SO_3, and Na_2SO_4 to be $P_{SO_2} = 40$, $P_{SO_2} = 3.0$, $P_{SO_3} = 10^{-9}$ at 700°, and with the liquid phase, glass, present the values will be raised somewhat. Hence CO_2 will not attack glass, and SO_2 at 1 atm. pressure will only attack at a temp. some distance below the softening point. As, however, the SO_2 content of the burned gases at the edge of the flame varies from 2×10^{-5} atm. upwards, if at 700° only 0.01% of this were converted into SO_3, the pressure of the latter would be 2×10^{-9}. Thus it appears probable that there is, within the variation of the limits of the S content of town gas, an amt. which, if exceeded, would cause sufficient pressure of SO_3 at the edge of the flame to give solid Na sulfate (or less probably silica).

J. S. C. I.

99. Heat balance of a plant consisting of an air-steam blown gas producer and a glass tank furnace. M. W. TRAVERS. *J. Soc. Glass Tech.*, **5,** 166–83(1921).—A detailed analysis of the combustion and melting processes, with consideration of heat losses, gave the following data: In a tank working at 1400°, with regenerators for preheating gas and air to 600°, there would be a fuel efficiency of 35% (the remaining 65% being lost outside the furnace), while, of this energy, 26% would be lost through the furnace walls, and 9% only would be used in melting glass. The coal consumption per ton of glass would be 0.94 ton. In a similar tank where gas and air were preheated at 800° the fuel efficiency would be 45%, of which 12% would be used for melting glass, and 0.73 ton of coal would be used per ton of glass. Finally with air and gas preheated to 1000° the fuel efficiency would be 55% (44.5% used for melting glass), the coal consumption per ton of glass being 0.60 ton. J. S. C. I.

100. A study of brown glass milk bottles. A. W. BITTING. *Glass Industry*, **3,** 157(1922).—It was found that when milk was exposed to the sun simultaneously in brown and clear bottles that the contents of the brown bottles were heated from 3° to 5° higher. The quantity of bacteria and acidity was increased so that the milk soured much more quickly in the brown bottles. The bacterial increase and change in compn. seemed to be more marked than could be accounted for by the difference in temp. alone. Clear glass evidently permits the strong light to exercize some inhibiting effect on the organisms while the brown has a less restraining influence. Milk when exposed to a strong light may acquire a tallowy taste, and sometimes a rich looking milk will take on a dead or chalky appearance. On these two points the amber bottle showed an advantage over the clear glass. J. B. P. (*C. A.*)

101. Heat balance for a 25-ton glass tank. F. J. DENK. *Glass Industry*, **3,** 109–11, 135–7, 151–3(1922). J. B. P. (*C. A.*)

102. Solubility and decomposition in complex systems (glass and ceramic ware). G. W. MOREY. *J. Soc. Glass Tech.*, **6,** 20–30(1922).—M. discusses first the 3-component triangular diagram H_2O–K_2O–Cr_2O_3, points on the side of the triangle representing binary mixts. and points inside ternary mixts. (cf. Schreinemakers, *Z. physik. Chem.*, **55,** 71(1906)). The diagram may be used to differentiate between compds. sol. in H_2O, *e. g.*, $K_2Cr_2O_7$ and those decomposed by it, *e. g.*, $K_2Cr_2O_{10}$. A similar diagram for H_2O–

K_2O–SiO_2 at various temps. up to 1000° was then studied. It is stated that the first action of H_2O at ordinary or moderate temps. on glass or ceramic ware is one of decompn., followed by the soln. of more or less of certain of the decompn. products. Tests on the durability of such silicates are rarely carried to completion and are thus really detns. of the rates of decompn. under more or less definite conditions. The effect of variation of conditions is dealt with and the paramount importance of rigidly defining these is shown. G. S. F.

103. Apparatus for controlling annealing of glassware and annealing without pyrometers. F. TWYMAN. *J. Soc. Glass Tech.*, **6**, 45–68(1922).—A rod of glass of the same compn. as that to be annealed is put under a strain producing deformation and is placed in the annealing chamber alongside the other articles. In two forms of the app. the extent of the failure of the rod to recover its usual position on removal is used to det. the extent of annealing, and in two other forms an additional small stress is applied in such a direction as to tend to increase the deformation; the point at which, strain having been released, the deformation begins to increase continuously, is taken as the annealing point. A method of using one form for detn. of the actual annealing temp. is described. An appendix gives a summary of formulas governing annealing, *e. g.*, variation of viscosity with temp. G. S. F.

104. Critical examination of methods commonly used in determining durability of glass. W. E. S. TURNER. *J. Soc. Glass Tech.*, **6**, 30–45(1922).—Four methods of test are considered. (1) Surfaces of glass vessels. It is not easy to arrange that a given vol. of reagent always acts on a definite area, especially when the reagents are boiling or agitated. (2) The use of plates or slabs of glass has the advantage that the area in contact with the reagent or its vapor is readily controlled. To obtain good results the surfaces should be ground and polished. (3) The use of powd. glass permits results to be obtained quickly by reason of the increased surface exposed, though for comparable results it was necessary to adopt a fixed grading of grain size (*e. g.*, 20 to 30, or 40 to 50 mesh), and to wash off any fine dust with alc. before the detn. (4) The autoclave test (Baillie and Wilson, *Ceram. Abs.*, **1** [10], 260(1922)) with water is not very satisfactory, since its results are not always in harmony with those given by water at ordinary pressures. The danger of trusting to loss in weight of a glass as a measure of attack is shown by examples in which samples actually gained weight owing to hydration. The detn. of the alkali extd. is stated to be easily possible only when water is the corrosive agent. The most accurate method, though slowest, is the detn. of the total matter extd. The need for a standardized method of test is emphasized. G. S. F.

105. Action of various analytical reagents on chemical glassware. W. E. S. TURNER AND T. E. WILSON. *J. Soc. Glass Technology*, **6**, 17–20(1922).—The tests were made on 3 types (two English, one French) of chem. glassware; in most cases the soln. was kept in contact with the glass for 3 hrs. at 100°. HNO_3 (d. 1.2), and $2N(NH_4)_2S$ soln. had but little action on the glasses, but they were attacked to an appreciable extent by 0.5 *N* and 0.25 *N* Na phosphate soln. The French glass was attacked to a greater extent than were the English glasses by the Na phosphate solns., while there was but little difference between the 3 types as regards their resistance to alkali hydroxide solns., showing that the corrosive action of the alkali salt solns. was not due entirely to their alky. J. C. S. (*C. A.*)

106. Re-annealing of glass. W. A. WHATMOUGH. *J. Soc. Glass Tech.*, **5**, 44–54 (1921).—The annealing of a glass prevents the development of strain only, but re-annealing, by heating glass to its softening point, releases strains already present. High ring strain is produced in articles such as specimen tubes made from glass tubing by machines with high velocity burners, and to remove this W. constructed a re-annealing oven which is very successful. In its present form it consists of a tunnel lehr, 9 in. sq.,

shaped like an inverted siphon, the mouth of the short entrance limb being at a lower level than that of the longer exit limb. The central horizontal portion is a fire clay muffle, heated by two rows of burners which can be accurately adjusted. The bottom of the tunnel, on which an endless chain tray track runs, is of cast iron, and the lagging is of slag wool between metal plates. In both limbs are draw-off valves for hot gas, and nine pyrometers are inserted. The track can be drawn through at varying rates. To prevent the cracking of long tubes by "steaming" an oven is constructed over the hot end of the long limb to give articles a preliminary warming. W. follows the conditions of the critical annealing curve as worked out by English and Turner (*C. A.*, **12**, 2240). J. S. C. I.

107. Examination of glass by polarized light. S. NAKAMURA. *J. Soc. Glass Tech.*, **5**, 57–61(1921).—N. describes a strain tester for optical glass slabs in which a sheet of black glass is used as polarizer, and is so fixed that, with polarizer and analyzer set with crossed planes, the slab is in the "diagonal position" when laid horizontally between. The degree of strain is indicated by the amt. of double refraction at the center of the slab, and this is measured by trial, a series of mica films of known retardation being used to obtain total extinction. J. S. C. I.

108. The melting of potash feldspar. G. W. MOREY AND N. L. BOWEN. *Am. J. Sci.*, **4**, 1–21(1922).—Pure synthetic orthoclase was prepared by crystg. a glass of the compn. $KAlSi_3O_8$ in a bomb with H_2O vapor. It was found that above 1170° this pure orthoclase decomposed into a liquid and leucite, the leucite becoming more apparent with increased temp. up to 1530°, where it disappeared. The significance of this fact to petrogenic theory is discussed. E. F. H. (*C. A.*)

109. Effect of magnesia on the resistance of glass to corroding agents and a comparison of the durability of lime and magnesia glasses. V. DIMBLEBY, C. M. M. MUIRHEAD AND W. E. S. TURNER. *J. Soc. Glass Tech.*, **6**, 101–7(1922).—The series tested ranged from $2Na_2O.6SiO_2$ to $Na_2O.CaO.6SiO_2$ and $2Na_2O.6SiO_2$ to $0.9Na_2O.1MgO.6SiO_2$, replacement of R_2O by MO being made in each case in ten successive steps. The resistance to boiling water, const. boiling HCl, $2N$ NaOH, and $2N$ Na_2CO_3 was detd. The magnesia glasses were superior to lime glasses over the whole range when water was the corroding agent, but were distinctly inferior to lime glasses in resistance to NaOH or Na_2CO_3. Na_2CO_3 was more corrosive to the magnesia glasses than was NaOH. Lime glasses were superior to magnesia glasses in resistance to HCl above the value MgO = 3.5 mols. %, but below this the substitution of MgO for Na_2O was more effective in improving resistance than the use of an equiv. amt. of CaO. G. S. F.

110. New plant of the United States Sheet and Window Glass Company at Shreveport, Louisiana. J. B. KRAK. *Glass Ind.*, **3**, 171–80(1922); illus. J. B. P. (*C. A.*)

111. Examination and extension of Zulkowski's theory of relation between the composition and durability of glasses. W. L. BAILLIE. *J. Soc. Glass Tech.*, **6**, 68–101 (1922).—Zulkowski (*Chem. Ind.*, **22**, 280–92; **23**, 346–59) connected the no. of mols. of simple silicates present in a glass per hundred mols. of double silicates with the durability of the glass, arguing that the simple silicates were the prime causes of instability. This theory gave good results with the plain potash-lead and soda-lime glasses, but samples contg. appreciable amts. of the R_2O_3 oxides were not considered. B. has studied 27 optical glasses, graded as unaffected, appreciably affected, or seriously affected by a filming test, by Zulkowski's method and shows that it fails with the glasses contg. R_2O_3 oxides. After quoting evidence in favor of the combination between Na_2O, Al_2O_3, and SiO_2 and of the beneficial effect of Al_2O_3 and B_2O_3 on the durability, the R_2O_3 oxides are regarded as forming silicates of the type $3MO.R_2O_3.xSiO_2$ and the remaining constituents as forming simple and double silicates as in the original theory. These com-

plex silicates are considered to be not inferior to the double silicates in durability. The general expression for the mol. percentage of simple silicates or "reactivity coeff." is developed as $(c-d)(c+d-3b)/(c+d)$, where a, b, c, d, denote molar percentages of SiO_2, R_2O_3, MO, and R_2O resp., for the usual conditions when $(c+d)>3b$. When $(c+d)<3b$ complex silicates with higher R_2O_3 content are regarded as being formed, and as being very stable, though excessive amts. of R_2O_3 may give unfavorable results, tending to devitrification and ready attack by alkali, or ready hydration in the case of B_2O_3. The theory can be regarded only as a second approximation, and while general durability can be predicted from the compn. of the glass, the behavior towards any particular reagent is uncertain. Further differences may be expected among different R_2O_3 oxides in equimolar proportions. Various tables of results are given in support of the theory. Sixty-five glasses were examd., and agreement in most cases was good. Values for "reactivity coeff." of more than 10 show an altogether unsuitable glass, of more than 5, unsuitable for chem. ware, while the value for good chem. ware is less than 3 and generally below 2. The acidity index of the glass, $a/(c+d)$, does not appear to be connected with the durability. Among the probable causes of discrepancies between the calcd. and observed results are insufficient "plaining" of the glass leading to incomplete formation of the double silicates and a corresponding excess of simple silicates, defective mfg. processes leading to cordiness and inhomogeneity generally, and reliance on a limited no. of tests to det. durability, and different methods of prepg. test pieces. The desirability of a varied range of tests for durability is stressed and B, in arriving at his results adopted the method of giving points to the glasses. Thus a no. was allotted to each glass in every test, indicative of its order of resistance to the agent employed. The sum of these numbers for a glass, divided by the no. of tests, gave its av. no. of "points" and these were the figures used in comparisons, as being the fairest and most impersonal. G. S. F.

112. Producer gas as fuel for the glass industry. C. D. Smith. *Nat. Glass Budget*, **38,** No. 18, 1, 16–7(1922). J. B. P. (*C. A.*)

113. The annealing of glass. H. W. Hess. *Glass Worker*, **41,** No. 51, 11, 27 (1922).—In making ware with automatic machines care is needed to prevent devitrification of the glass. The polariscope is of great assistance in securing proper annealing. J. B. P. (*C. A.*)

114. Boiler gage glass problems. H. W. Hess. *Glass Worker*, **41,** No. 52, 11 (1922). J. B. P. (*C. A.*)

115. Testing gage glasses. H. W. Hess. *Glass Worker*, **42,** No. 1, 11, 29(1922).—Various methods are described briefly and weaknesses noted. A dipping test from hot Hg to cool water is considered most satisfactory. J. B. P. (*C. A.*)

116. Copper ruby glass. H. Kühl. *Sprechsaal*, **54,** 383(1921); *J. Soc. Glass Tech.*, **6,** 8a–9a.—One of the oldest and most interesting works on Cu ruby glass was that by P. Ebell (1870), who, although writing before colloidal chemistry was understood, drew sound conclusions as to the cause of the color. The prepn. of Cu ruby, however, was, on the whole, not so well understood as that of Au ruby. As the two were of similar nature, the amt. of the metals used to produce the same intensity should not differ widely, but whereas, according to Müller, 1 part of Au per 50,000 parts of glass gave a bright red color, the amt. of Cu needed was uncertain, and many views were incorrect. Randau, for instance, had stated that the weight of Cu should be 2% of that of the batch. By the use of methods similar to those for prepg. gold ruby, K. had obtained the color by the use of 0.02% of Cu. Haller prepd. a beautiful ruby from the batch: sand 100, potash 30, soda-ash 2.5, limespar 12, Cu sulfide 0.02, Na_2S 0.026, borax 0.024. A ruby batch patented in 1882 had the compn.: fine sand 2000, red lead 400, potash 600, lime 100, Ca phosphate 20, K bitartrate 20, Cu_2O 9, SnO_2 13. The

Cu here was only 0.40% of the weight of sand used. Randau used a much higher propn. in the batch: sand 100, soda 18, SnO_2 20, CuO 15, Fe oxide 10. In the manuf. of copper ruby, the batch should be one melting at not too high a temp. and allowing normal working, while the Cu salt should be easily reducible and very finely divided. The melt should be of a reducing character. In many failures the fault had been due to the use of a too strongly basic batch resulting in the production of crystals of Cu_2O, in which case a liver-brown color was obtained with incident light. H. G. (*C. A.*)

117. The application of self-luminous colored decorations in the glass and ceramic industries. O. PARKERT. *Sprechsaal*, **55,** 34(1922); *J. Soc. Glass Tech.*, **6,** 23a.—The prepn. of self-luminous paints, now coming into use in America and France, depends on the use of phosphorescence phenomena such as are associated with the sulfides of the alk.-earth metals, and of ZnS. In addn. to the sulfide, such as that of Ba, Sr, or Ca, an active metal is added in the form of a salt of Bi, Mn, or U. Further, a flux is needed, and is usually provided by a salt of Li, Na, or K. A mixt. which gives violet radiation is said to be obtained from 20 g. CaO, 5.5 g. S., 2 g. starch, 1 cc. Bi nitrate soln., 0.12 g. KCl, 0.14 g. NaCl. This mixt. is heated for a lengthy period in a muffle at 1200°. For yellow colors, one may use 100 g. $SrCO_3$, 100 g. S, 0.5 g. KCl, 0.5 NaCl and 0.4 g. Mn chloride. For a green color, Sr thiosulfate 60 g., U nitrate 6 g., and Bi nitrate 10–12 g.; while for a red color, $BaCO_3$ 44 g., S 6.5 g., Li carbonate 1.2 g., Na carbonate 0.04 g., Rb carbonate 0.5 g. may be used. The mixt. is heated to glowing and appears to be most efficient when cooled rapidly. It should have a fine white appearance. Before use it is subjected to the action of strong illumination, which may be sunlight, or an incandescent gas mantle, or a Hg vapor lamp. For glass or ceramic processes, the prepn. may be mixed into the liquid glass or applied as in the glaze to porcelain. It may also be applied as a paint or as a spray. H. G. (*C. A.*)

PATENTS

118. Non fragile glass. P. B. CROSSLEY. Brit. Pat. 152,780, July 22, 1919; *Ill. Off. Jour.* (Pat's.) No. 1668, p. 5676, Dec. 31, 1920. Non fragile glass, which can be rolled, forged, extruded, cast, etc., is made by dissolving in the dry state such silicate as micaceous or asbestos minerals in molten glass or a similar silicate. The glass, etc., is chosen so as to melt at a temperature below the temp. at which the hydrous silicate effloresces. If the product is to be machined an excess of mica, etc., should be present over the amount necessary to form a satd. soln. WM. M. CLARK

119. Sealing electrical conductors into quartz. SILICA SYNDICATE, LTD. Brit. Pat. No. 185,952. Sept. 7(1921); *Ill. Off. Jour. Pat's*, p. 4891(1922). Covers a seal for elec. conductors in vitreous vacuum vessels comprising two or more wires passed thru sep. holes in a vitreous plug, or thru sep. vitreous tubes, these being placed in an enclosing vitreous tube and the whole fused together. With sketches.

WM. M. CLARK

120. Process of manufacturing optical glasses. GENZO SHIMAZU. Japan 43,203, Aug. 1, 1922. Oxides of lead are prepd. by oxidizing lead-powder by means of natural oxidation or other methods without melting. They are used to compose batches for optical glass together with quartz, sodium carbonate, lime and other usual raw materials. S. KONDO

121. Improvement in boro-silicate glass. KITSUZO FUHA. Japan 42,161, March 31 (1922). The new glass has the following compn: Silica 66.0–67.5%, alumina 1.0–1.75%, soda 7.0–8.0% and boric anhydride 22.0–24.0%. The glass adheres more air-tightly to tungsten-wire, resists more sudden changes of temp. and resists weathering better than the already-known boro-silicate glasses. S. KONDO

122. Glass molds. R. L. FRINK. Brit. 183,582, April 26, 1921. Metal molds for glass working are made with a porous or finely pitted surface. Such molds may be

made from an alloy of Al or Cu with Cu, Ba, or Mg, the surface being rendered porous by treating it with an alk. soln. A suitable alloy contains about 2% of Ca or Ba. In making such an alloy, it is recommended that an alloy contg. 75% of Al and 25% of Ca, etc., be first prepd. at a temp. of 500–1100°, and that this be added in the required proportion to pure molten Al. For use the molds may be dipped in H_2O, paraffin oil, etc. (*C. A.*)

123. Alkali metal silicate production in blast furnaces. S. PEACOCK. U. S. 1,425,048, Aug. 8. An alkali metal silicate suitable for *glass making purposes* is made by igniting a charge of C, SiO_2 and Na_2CO_3 in a blast furnace and withdrawing the slag produced. (*C. A.*)

124. Furnaces containing melting pots or crucibles. J. U. MCDONALD. Can. 221,315, July 25, 1922. (*C. A.*)

125. Glass. F. M. LOCKE. U. S. 1,431,166, Oct. 10. Glass having a coeff. of expansion of not more than 0.0000035 and adapted for the manuf. of culinary or chem. ware is formed of SiO_2 78, B_2O_3 15, Na_2O 4, CaO 1, K_2O 1 and Al_2O_3 1%. (*C. A.*)

126. Glass. A. L. DUVAL D'ADRIAN. U. S. 1,430,725, Oct. 3. $MgBr_2$ 1/2–50, lbs. or other Br salt is added to a glass-forming compn. which may contain sand 1000, Na_2CO_3 360–380 and limestone 200–220 lbs. in order to eliminate greenish color due to Fe present in the materials used. (*C. A.*)

127. Continuous annealing furnace. M. VAN MARLE. U. S. 1,429,380, Sept. 19. Articles are carried through the furnace on an endless conveyor which passes through seals at both ends of the furnace. (*C. A.*)

128. Glass. E. C. SULLIVAN and W. C. TAYLOR. Can. 220,748, July 11, 1922. A glass having a linear expansion coeff. of more than 0.000012 and a hardness of 640° contains SiO_2 42, soda 19, potash 5, BaO 19, and Al_2O_3 15%. Cf. *C. A.*, **15**, 1608; **16**, 1644. (*C. A.*)

129. Glass. W. C. TAYLOR. Can. 220,441, July 4, 1922. A glass contg. SiO_2 B_2O_3 Li_2O and Al_2O_3 has a coeff. of expansion of less than 0.0000056. (*C. A.*)

130. Hollow glass articles. E. FRANK. U. S. 1,420,996, June 27. A long clear glass tube is coated with opaque material at intervals preparatory to reheating and blowing to form incandescent lamp bulbs or similar articles. (*C. A.*)

131. Non-shatterable glass. O. S. MARCKWORTH. U. S. 1,421,974, July 4. Assembled laminas of glass and celluloid are immersed in a soln. of fusel oil, camphor, and methyl salicylate at a temp. of 24–35° and the laminas are subjected to pressure together and more highly heated in the soln. (*C. A.*)

132. Melting glass. R. GOOD. U. S. 1,421,210–11, June 27. Mech. features. (*C. A.*)

Enamel

133. Something better in enamel smelters. H. E. DAVIS. *Chem. and Met. Eng.*, **27**, 1210(1922).—A description of a new type of enamel smelter, using oil as fuel. The general construction of the furnace and some data as to the cost of operation are given.
R. R. DANIELSON

134. The development of industrial electric heating for low temperature enameling. W. S. SCOTT. *Trans. Am. Electrochem. Soc.*, **42**, preprint, 1922.—Early expts. are recorded which point out the great importance of adequate ventilation of an elec. enameling oven. During the drying of the enamel combustible gases are evolved and these must be withdrawn in such a way as to avoid explosions. The suspensions and arrangement of the heating units are discussed. Typical elec. oven installations of the automotive and typewriter industries are illus. and described in detail. Cf. *C. A.* **16**, 3263.
C. G. F. (*C. A.*)

135. Enameling. N. MEURER. Brit. 179,216, Nov. 27, 1920. In enameling metal, ceramic, or other heat-resisting articles by spraying enamels, glass, or mixts. rich in quartz on to the articles by means of gases under pressure, the surface of the article is heated by the spraying jet to the fusing temp. of the coating material, and the flame that effects the melting and heating has a reducing action to prevent oxidation. A suitable construction is specified. (*C. A.*)

136. Enameling furnace. TAKEO NAGASAWA. Japan 39,806, Sept. 8, 1921. A muffle furnace in which materials are revolved during heating is specified. (*C. A.*)

Cement, Lime and Plaster

137. Storage and transportation of portland cement. W. F. MYERS. U. S. Bureau of Mines, Serial No. 2377(1922).—See *Bull. Amer. Ceram. Soc.*, **1** [10], 264 (1922). R. R. DANIELSON

138. Working a lime-stone quarry. PIERRE PREVOST. *Rev. Mat. Constr. Trav. Pub.*, **157,** 189–91(1922).—At Louvières, Vitry-Le-François (Marne, France), 4,500 T. of lime-stone were blasted at one time by detonating 230 kgs. of dynamite set in four holes, 20 cms. in diameter, drilled 19 m. deep and 6 m. apart. LOUIS NAVIAS

139. Tests on the double burning of lime, and the value of cements of high hydraulic index. F. B. JEANNERET. *Rev. Mat. Constr. Trav. Pub.*, **158,** 213–5(1922).—(1) Penetration tests in alk. sulphide solution are given for diff. types of pure binders, for tamped 1:3 mortars, and for untamped 1:3 plastic mortars. (2) Graphically and in table form are given the results of tests on lime burned directly to 1400° and on samples first fired to 1100°, then cooled, made into blocks, and fired to 1300–1400°. Chem. compns., and results on compression and tensile strengths for the cements are given. The only conclusion drawn is that binders of high hydraulic index show their max. properties when they have a $CaCO_3$ content of 72–75%. LOUIS NAVIAS

140. Function of the laboratory in cement manufacture. J. C. WITT. *Cement Mill and Quarry,* **21,** No. 9, 31–2(1922).—From selecting the raw materials to turning out the finished product, cement manuf. which is essentially a chemical process, requires lab. control. J. C. W. (*C. A.*)

141. Some generalizations on the influence of substances on cement and concrete. J. C. WITT. *Philippine J. Sci.*, **17,** No. 10(1922); cf. *C. A.*, **12,** 1113; **13,** 895.—The final results obtained in a research started at the Bur. of Science, Manila in 1916 are given. The effect of NaCl, $ZnCl_2$, $CuCl_2$, $NaNO_3$, KNO_3, NH_4NO_3, Na_2SO_4, $ZnSO_4$, $CuSO_4$, $NaHCO_3$, and $KHCO_3$ has been studied. The 2700 tensile tests indicate that when cement is mixed with normal solns. of these salts the general effect is a slight decrease in strength, though in many cases there is an increase. J. C. W. (*C. A.*)

142. The remelting of acid blast-furnace slags and cement. RICHARD GRÜN. *Stahl u. Eisen,* **42,** 1158–67(1922).—The prepn. of Portland cement out of acid blast-furnace slag is possible by adding lime and clay to the hot liquid slag. The clay should be added before or with the lime. The addn. of lime up to the compn. of Port. cement is not necessary but may be limited to about 50%. R. S. D. (*C. A.*)

143. The effect of sulfur compounds on cement. J. C. WITT. *Philippine J. Sci.*, **17,** No. 10(1922); cf. *C. A.*, **12,** 88, 616; **13,** 3300; **15,** 1835.—The final results obtained in a research started at the Bur. of Science, Manila, in 1915 are given. Five-year neat and mortar briquets show little decrease in strength due to the presence of Na_2S in the mixing water in quantities up to 1 g. S^{--} per l. A max. decrease of approx. 1/3 the strength results with 10 g. S^{--} per l. Three-year neat and mortar briquets made with cements containg. varying amts. of SO_3 show little difference in strength (up to 5% SO_3). Decided lowering of strength and in some cases disintegration, are caused by 9% to 10% SO_3 (in 5 of the 6 cements used). J. C. W. (*C. A.*)

144. The utilization of the waste heat of rotary cement kilns. J. BIED. *Chimie et industrie*, **8**, 528–30(1922).—The amt. of heat carried away by the waste gases in the dry process is calcd. It is proposed to use this heat for generating steam. Installations at the plant of the Trinity Portland Cement Co. (*Rock Products*, No. 23, Nov. 5, 1921) and at the Leimen plant of the Heidelberg Portland Cement-Werke (E. Schott, *Ton-Industrie*) are described. Schott proposes a "compound kiln," consisting of a rotary for clinkering and a vertical for decarbonating by means of the waste gases (at 1300°) from the rotary. A certain amt. of coal would be required in the vertical kiln.
A. P.-C. (*C. A.*)

145. Industrial chemistry problem relative to the treatment of cement. (Influence of the addition of calcium chloride on the strength of Portland cement.) C. R. PLATZMANN. *Zement*, **11**, 137–8, 151–3(1922); *Chimie et industrie*, **8**, 614(1922); cf. *C. A.* **16**, 2586.—$CaCl_2$ 2.4–5% was added with the water in mixing the mortar to hasten hardening and prevent cracks due to shrinking. The temp. of setting was detd. by means of Killig's app. Though this indicated only part of the heat generated, the relative temps. obtained were interesting. The tests were carried out with a com. cement and with a slag cement. The av. tensile and crushing strengths at the end of various periods of time and for various percentages of $CaCl_2$ are tabulated. The addn. of $CaCl_2$ improves the constancy of the vol. and increases the generation of heat during setting. Finally, the cement is less readily attacked by various gases which in the presence of water form H_2SO_3 and H_2SO_4. A. P.-C. (*C. A.*)

146. A Rumanian cement mill. P. F. BAGGE. *Concrete* (Cement Mill Section), **21**, 19–25(1922).—B. discusses the raw materials, fuel, labor, equipment and mfg. processes of the Tordaer Cement Works. J. C. W. (*C. A.*)

147. A study of conditions causing disintegration of cement under the "accelerated" test. A. G. FLEMING. *J. Soc. Chem. Ind.*, **41**, 300–2T(1922).—That the accelerated steam test on cement is unnecessarily severe and does not always indicate the quality of the cement has led to these conclusions from a series of expts.: (*a*) The chem. compn. of an av. Port. cement gives little guidance as to its possible behavior under the accelerated test. (*b*) Unsound cement stored under water shows a marked improvement compared with that stored in air, either dry or moist; the natural storage for cement, at any rate during hardening, is under water. (*c*) Mortars poor in unsound cement improve more rapidly than mortars rich in unsound cement. There is thus little danger of disintegration of a water-stored concrete made from what are ordinarily termed "poor" cements. (*d*) Mortars in practice do not exhibit the weakness of their neat cement. (*e*) Mortars and concretes are improved by water-storage; concrete should be kept moist, at any rate until completely set. The disruptive force exhibited in the accelerated test is due principally to the free lime incorporated in the clinker particles and this force is not discovered except by rapid hydration. That the combination of the alkali bases with CO_2 from the air and S from the sulfides of the clinker may be also responsible for unsoundness is indicated from the expts. Fine grinding of raw mix to insure more intimate combination of the elements has eliminated much of the danger of unsoundness. C. N. W. (*C. A.*)

148. Electric cement. ANON. *Rev. ing. index tech.*, **29**, 155–7, 197–8(1921); *France-Belgique*, **1**, 71–2, 199–200(1922).—"Electric cement" is an aluminous cement manufd. in the elec. furnace. The essential component is $Al_2O_3.CaO$ or the eutectic $3Al_2O_3.5CaO$. The hydraulic index is generally above 1. The apparent d., with a degree of fineness such that 5% remains on a sieve of 4,900 meshes per cm^2., is not over 1. When tested hot with LeChatelier cylinders it does not swell, and its contraction on setting is the same as that of ordinary cement. It is not decomposed by the sulfates of the alkalies or alk. earths or by sea-water; it hardens rapidly; with 300 kg. of cement

to 1 m.³ of sand, the strength after 48 hrs. is more than double that of a similar mixt. of artificial Port. cement after 90 days. A. P.-C. (*C. A.*)

149. Process of burning pulverized fuel in which Portland cement is obtained as by-product. TSUNEICHI FUJIYAMA. Japan 43,420, Sept. 8, 1922. Lime and small amts. of quartz or other similar subs. are mixed to pulverized fuel in such a propn. that they compose Port. cement with the ashes of the fuel. The pulverized mixt. is burned with air-blast to heat boilers or other app. and to produce cement-clinker at the same time. S. KONDO

150. Marble-cement. KIHICHI NAKAMURA. Japan 43,347, Aug. 28, 1922. Pieces of glass or pattern-plates of various shapes are scattered on a base-plate which has previously been coated with celluloid or glue and has a frame on it. A colored mortar composed of sodium silicate, Port. cement, coloring matter and water is poured on the plate as thick as the glass-pieces or the pattern-plates. They are then picked out and similar mortar of different color is poured in their places. Then cracks are formed in the mortar by inserting a spatula to the surface of the film and moving it at places. The cracks are now filled with similar mortar of another color. The artificial stone, thus obtained, is soaked in the soln. of sodium silicate and is then polished. Marble, granite and other natural rocks can be imitated by the process. S. KONDO

151. Process of manufacturing paving material. KOMAKICHI KATO AND CHIAKI KAMIBAYASHI. Japan 42,701, May 30, 1922. The ground Soja bean is treated with the soln. of an alkali. Any sol. aluminium salt and coal-dust are added to the product. The mixt. is used in paving together with cement, lime, sand, etc. S. KONDO

152. Material for artificial stone. TOYOJI HATANAKA. Japan 42,502, May 8, 1922. A white powder consisting of magnesia, zinc oxide, ground glass or other mineral subs., white Port. cement and clay, and a soln. of magnesium chloride, Gloiopeltis furcata (a kind of glue) and alum in water are used in making artificial stones. Magnesium chloride is sometimes excluded from the soln. S. KONDO

153. Paint for water-proofing cement. NAKAJIRO MANO AND RYUJIRO YANAKA. Japan 42,350, April 18, 1922. Fatty acid and solid paraffin are dissolved in naphtha of low m. p. S. KONDO

154. Pitch-cement. ICHITA KISHI. Japan 42,291, April 12(1922). It relates to a pitch-cement which is prepd. by melting a mixt. of the pitch of petroleum, coal, brown coal or peat and magnesia. S. KONDO

155. Magnesia sheet. SACHIO MIKI. Japan 42,194, April 4(1922). Wires of a coarse wire-netting are cut at many points and their ends are bent up- or downwards. A paste composed of magnesia and fibrous subs. is applied on both surfaces of the netting. It is used for insulating heat. S. KONDO

156. Process of manufacturing plaster of Paris. SEIKICHI FUKUZAWA, ITO FUKUZAWA AND TOYO GIPS CO. Japan 43,679, Oct. 11(1922). The product of chem. reaction between sulphuric acid and lime is left in a heap until the grains get spheroidal shape. They are then washed with water to get rid of magnesium sulphate. They are again left in heap until they get spheroidal shape. They are then used in the manuf. of plaster of Paris. S. KONDO

157. Asbestos-cement. R. V. MATTISON. U. S. 1,423,000, July 18. A mixt. adapted for making shingles or blocks is formed from hydraulic cement, asbestos fiber, H_2O and heavy petroleum oil. (*C. A.*)

158. Oxychloride cement. C. CATLETT. U. S. 1,422,337, July 11. Solid lime and solid $CaCl_2$ are mixed in finely divided condition to form a stable oxychloride nearly free from a tendency to form lumps. Cf. *Ceram. Abs.*, **1** [4], 122(1922). (*C. A.*)

159. Molding and coloring artificial stone. B. R. WHITBY. Brit. 178,736, May 10, 1921. Colored artificial stone with a glazed surface is produced by filming one side of a glass plate with cement mixt. colored as required, allowing the film to set on the glass, and then placing the latter in a mold, of which it forms a removable lining, and filling up with cement, concrete, etc. (*C. A.*)

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EDITORIALS

OUR SILVER JUBILEE

Industrial ceramics has had twenty-five years of unselfish promotion of art and science; first by the ten men who originated the idea of a Society for this purpose, then by the twenty-one men who were the charter members and lastly by the nineteen hundred members of the American Ceramic Society. A quarter of a century has passed since the original ten met in Pittsburgh to discuss the advisability of organizing a coöperative means of obtaining and disseminating data and information on technical and scientific ceramic problems. Five of the original ten men met in Pittsburgh on the twelfth of last February with five hundred other ceramists to celebrate the twenty-fifth anniversary of that first council of ten, and to consider the technical and scientific problems of the present day ceramic manufacturing.

A visualization of the present day larger appreciation by manufacturers of the service rendered by the American Ceramic Society may be had from the fact that four years ago the entire Convention was held in the room which this year the Whitewares Division alone crowded. Four years ago the Divisions were not organized; this year seven Divisions held two sessions on each of the two days with programs that totaled 190 original contributions, several committee reports, discussions and questions.

The large attendance, the excellence of the entertainment by the Pittsburgh Section and particularly the large amount of valuable information developed by the "seven conventions in one" fittingly honored that meeting of the original ten men of twenty-five years ago. The rapidly increasing attendance at these Conventions is evidence that organized coöperation in the creation and dissemination of technical and scientific ceramic knowledge is of increasing value to ceramic manufacturing.

TECHNICAL INVESTIGATION AND RESEARCH BY TRADE ASSOCIATIONS

Associations of manufacturers of like products are organized primarily for collective search for the most economical tariff, traffic, labor, manufacturing and management terms and means. In this they are coöperating directly with such of the public as are interested and with the federal and state authorities representing the public at large. Trade associations in America have increased in numbers until now there are several hundred whereas twenty-five years ago there were only a few. Trade associations are recognized as essential to the economic welfare not only in this country but also in all countries where manufacturing is carried on to any extent.

Manufacturers in America have had many years' experience with legal restraints and it should be expected that price fixing and other practices unfair to the public should continue to be subject to rigid restraint. The limiting laws of today, however, are not in harmony with the need of cooperation in business. The Sherman Act was directed against consolidations of capital at a time when collective action through trade associations was not a factor either in manufacturing or business. Consolidation of capital that eliminates competition is a vastly different thing from collective action through trade associations. The former is often (although not always) without regard to public welfare whereas trade association activities have been most largely of direct benefit to the general public. Consolidation of capital gives domination in business; collective activity through trade associations develops individualism, improves business standards and eliminates waste in production and distribution. Trade associations are the essential contact agents for government bureaus, and the effectiveness of government bureaus in their aid to manufacturers has increased with the increase in strength of the trade associations. Coöperative investigations supported by producers, consumers and the public are possible only when the producers and consumers each are organized.

It is true that evil practices are possible with trade associations. Any collective activity can be used for conspiracy against public interests and trade associations are no exception.

Among the most beneficial activities of trade associations are those that will improve quality of product, stabilize labor relations, and reduce cost of manufacturing. Technical investigations, standardization of materials and products, and elimination of wastes are the means by which trade associations obtain these results.

The AMERICAN CERAMIC SOCIETY through its officers and committees is pledged to promote investigations by trade associations in coöperation with such research organizations as federal bureaus, Mellon Institute and the commercial laboratories. Coöperative investigation by trade associations brings the needs and the benefits directly to managing employers; insures engagement on the most essential and vital problems; stages the investigation on plant conditions and takes recognition of the viewpoints of the supporting firm members, thus making the data, observations and conclusions of immediate and direct benefit and value. This short cut contact between the several plants and the central laboratory with its broadening influence alike on the plant operators and the investigators can be had in no other way than through trade associations. It clears away the secrets in manufacturing which have made the application of results of research so slow in the past. It makes possible a study of problems on a large scale in an authoritative manner, establishing more economical production practices. When an association of users will collaborate with an association of producers on a problem, ware of the required quality will be produced and marketed to the advantage of both parties and to the public at large.

The function of the AMERICAN CERAMIC SOCIETY in this scheme of cooperation affects in no wise this direct contact between the association of producers and the research laboratories. There is a need for the AMERICAN CERAMIC SOCIETY devoted as it is exclusively to the promoting of research agencies and activities, gleaning all the information extant from the world's literature, making and preserving records of research, data and observations and in every other possible way not only building up a fund of information regarding materials, processes and products but also promoting the means of obtaining this information. The practical value in the work of the AMERICAN CERAMIC SOCIETY lies in the fact that it represents all ceramic industries and therefore brings to each all of value that has been obtained by the others. All ceramic manufacturing has many things of common interest. It may seem to be a "long cry" from the manufacture of glass or enameled ware to the manufacture of bricks, yet to one familiar with the technology involved there are practices, materials and processes that are common to each. It is much easier to see the similarity in problems of the whitewares group of manufacturers or in those of the heavy clay product group. There is value in manufacturers of a like product associating together on a program of technical investigation

through their trade association and by the same token there is value in all manufacturers having problems common to each being associated together.

The trade associations have found and proven the value in coöperative research. Some of them have continued their coöperative investigations over a period of years with increasing financial support. It is the hope of those who labor in the AMERICAN CERAMIC SOCIETY that every ceramic trade association will be so engaged.

The public and the legislators will soon realize the wide distinction between combined capitalization, in which individual concerns are merged, and the trade associations in which the individual concerns not only maintain their individuality but are strengthened in their economic and manufacturing position as individual concerns. Coöperation with their fellows and with representatives of the public on problems that affect directly the cost of production and distribution and the quality of the ware is a healthy combination of interests. If the AMERICAN CERAMIC SOCIETY can be as influential in promoting coöperative research by trade associations as it has been in promoting the establishment of government laboratories and collegiate ceramic departments it will have justified its support by manufacturers of ceramic products. This SOCIETY must continue to justify its existence by actual accomplishments, and no avenue for accomplishment is more productive than the promotion of technical investigations by trade associations.

PAPERS AND DISCUSSIONS

DISCUSSION ON "REFRACTORIES FOR OIL-BURNING FURNACES"[1]

By R. L. FRINK:—In the October issue of the *Bulletin of the American Ceramic Society*[2] I was much interested in the discussion on refractories for oil burning furnaces, and particularly the remarks made by my old friend, Mr. Greaves-Walker, regarding the effect of oil upon refractories, which he describes as a rotting, due to the impingement of the oil upon the surface of the brick and the minute explosions which take place, his theory apparently being that because of these minute explosions and the extremely high temperature occasioned at the instant of the explosion there is a disintegration of the surface. While he does not say that exactly, yet, to my mind, it is the only inference that can be made from the theory as expressed.

I am in part inclined to this theory but not in the effect which I infer from his statement, *i. e.*, that there is sintering or actual fusion of the brick at the instant of these explosions and a subsequent disintegration because of continued or repeated explosions, for if such were the case the surface of the brick would not have the appearance of being rotten, as he expresses it, but would be more inclined to have the appearance of glazed or vitrified surface and while it is true that in many instances this is the characteristic of surfaces obtained the majority of surfaces are quite different. Therefore I venture to present another theory, which I suggested some years ago before the SOCIETY as relating to the effect of water smoking upon the chemical and physical characteristics of clays. That is, the effect of a sudden or pronounced increase of temperature over local areas in comparatively short periods of time, when such areas of clay have been subjected to a water smoking condition or the absorption and adsorption of compounds of hydrogen and carbon, as tar, soot or the absorption of hydrogen carbon gases; and then if temperatures are produced which before complete oxidization of this carbon occurs there is a temperature gradient within the clay sufficient to disassociate the hydrogen and silicon the presence of a moisture compound of silicon and hydrogen will be formed, with the result that the free silica or silica which is in excess as related to other components of the clay will be removed in the form of a gas of the methane, acetylene and other series of hydrogen silicon compounds, leaving behind a more or less porous mass whose surface is usually discoloured by a re-disassociation of the silicon hydride compound and precipitation of silicon.

I remember quite distinctly that some years ago when discussing this theory, it created considerable amusement. However, I think that later

[1] Received November 21, 1922.

[2] *Bull. Amer. Ceram. Soc.* **1** [10], 229(1922).

it was conclusively proved, although whether or not it became generally known I do not know, that in the making of paving brick, the density, resistance to abrasion or rattle test and other qualifications were, in one or two plants, quite satisfactorily controlled, particularly in oil fired kilns by regulating the relation between oil vapor or gas, steam and air, all of them being related to temperature produced within the kiln.

Noticing this discussion of Mr. Greaves-Walker, it occurred to me that reopening our old controversy might enliven a subject which, if thoroughly investigated, would not only be interesting but helpful and important to the clay industry generally.

I might also call attention to a recent experience in the burning of heavy Mexican oil, in which we obtained an effect similar to that which Mr. Greaves-Walker describes, *i. e.*, the rotting of the brick and also the opposite effect of glazing, but in this instance it was found that the glazing took place at remote or distant corners of the furnace where there was no direct impingement of oil or oil vapor upon the surfaces of the brick and this blaze was a brownish or black color and was primarily caused by the presence of sulphur, tellurium and vanadium while the rotting or disintegration of the brick was of a character which could be accounted for by the theory above expressed, for upon chemical and physical examination of the surfaces and the structure of the remaining refractory material, it was quite evident that a considerable quantity of silica had been removed.

GLASS RESEARCH ASSOCIATION
LONDON, ENGLAND

DISCUSSION ON "CALCINING OF CLAYS"[1]

(1) Has there been any kiln designed and in use which will successfully calcine run-of-mine plastic fire clay to a temperature of cone 6–8?

(2) What is the most economical method of calcining clays? Compare calcining in ordinary kilns, in perpendicular furnaces, and in rotary kilns.

(3) What is the best and cheapest fuel to use in rotary kilns? What is the approximate cost to install, and operate, and the approximate capacity? Can powdered coal be used when calcining at a high temperature without injuring the clay?

MR. GREAVES-WALKER:—We have here this morning a rotary kiln expert. I do not know that he has ever gone into the question of calcining clays but the operation of the kiln would be the same in any industry. Some of you have undoubtedly had experience in calcining clays in updraft kilns. I know that some of you have had experience in calcining in ordinary down-draft kilns hence we should get a very good discussion.

Mr. Austin will start the discussion on this subject and give his opinion as to the usefulness of the rotary kiln as compared with the down-draft kiln.

[1] Refractories Division, St. Louis Meeting, February, 1922.

MR. AUSTIN:—Of course, for calcining I approve of the rotary kiln, but it all depends on just how much calcining you have to do and also on the fuel. The fuel would depend on where your kiln was located. You can burn very successfully with oil, gas, and dust coal.

As to the installation, you can make it cost most anything that you want for there are so many different types. When calcining clay you can get perfect combustion. A great deal depends on the operator of the rotary as to the production of such a kiln. There are so many different angles to it that I do not know where to commence but I will try to answer questions.

MR. GREAVES-WALKER:—Can you give us an idea what a small rotary kiln installation, the smallest installation you recommend, would cost?

MR. AUSTIN:—To begin at the fuel end, we have to have pressure to handle the fuel, and the amount of pressure needed will depend upon both the fuel and the clay.

There are so many old rotary kilns in this country, if you want to make an economical installation you can pick one up for very little money. Then again it depends on where you are located.

There are many one-unit installations for grinding coal; and a great many in other fields. These are high speed equipments that go to pieces quickly.

Again you can use fuel oil. There are many different systems for fuel oil each having certain advantages.

You can put in a one-unit installation for $2000 that will give you a production from 48 to 75 tons a day.

MR. GREAVES-WALKER:—I think this question of calcining clays is of interest to a number in the fire clay business, especially those in the St. Louis district, because here the crudest method is used, that of calcining in down-draft kilns. This is, undoubtedly, the most expensive method.

With the necessity for reduced costs, the time has come when it is important to find more economical methods of calcining clays. They are shipping clays a greater distance now than ever before and even this attempt at saving in freight by calcining at the mines is at the present rates worth while. There is the question whether it would be better to calcine at the mines or whether it is worth while hauling that moisture in bulk from the clay mines to the clay plants.

MR. KRUSEN:—Would the use of powdered coal for fuel in a rotary kiln have any effect on the clay?

MR. AUSTIN:—You would have the ash, but if you use white ash coal, it would not affect the clay so much. It might run the silica higher.

My idea of a clay kiln is different from most other kilns for the reason that with clay you would not have to do any extra calcining and the operation could be done very quickly. The cement proposition as you know is different.

I believe you could calcine clay by closing up everything and getting almost perfect combustion. You still get your ash but you could easily take care of that in a small kiln. You would not need any stack draft, hence it would be very economical. Personally, I prefer dust coal to any other fuel; you can get any kind of a fire you want without any loss of fuel. When you use fuel oil, you have an atomizer to contend with, and if it does not atomize properly, you do not get good results.

MR. HARVEY:—I would like to inquire to what percentage the ash will reach. How much coal do you have to use per ton of clay calcined? Calcining usually runs about cone 6 to 8. If you know how much coal you are going to use, you can easily figure out what the percentage ash will be. Then you can tell how much it will lower the fusion point of the clay.

MR. AUSTIN:—That is something else. Every rotary kiln which I have installed, with one exception, has operated at a very high temperature. Where we burned to cone 20, with a particular coal, it took about 30% of fuel based on the amount of dead burning material, or about 600 pounds to the ton. You get 30% of fuel for the amount of tonnage that comes out. Of course, with clay there would be a considerable increase over this in tonnage production per amount of fuel used.

MR. HARVEY:—Do you mean 600 pounds of powdered coal per ton of finished product up to cone 20?

MR. AUSTIN:—Yes, sir.

MR. ROY G. SMITH:—Mr. Austin has had experience with rotary kilns at high temperatures. We have had experience with rotary kilns at low temperatures. Perhaps between the experience of us both we may get somewhere in this figuring.

We have a plant that makes face brick from a low grade of fire clay. This plant made pressed face brick for a good many years until they got the idea that they could make stiff-mud brick to better advantage. They installed a stiff-mud outfit, as we use those words in the clay industry. They found that the drying shrinkage of this clay was such as to rupture the brick before they got dry and hence it was necessary to use grog in order to get the brick through the dryer. We came to the conclusion that the rotary kiln would be the only possible way of making grog in sufficient quantities.

We installed a rotary kiln, 6 x 60 feet. This one cost us $3500. It was twenty years old and originally cost $3000. The entire installation cost us $20,000. However, about one-half of that was clay handling equipment which might not be considered essential to the rotary kiln installation.

The preparation of the material is very important, and also the disposition of it after it is calcined. Coming out of the rotary kiln in quan-

tities, after being at that high temperature it is very difficult to handle. It is necessary to have a mechanical feeder of some kind to put it in. If you have large lumps or wet clay, you have another problem on your hands.

We installed this rotary kiln under a clay chute at the railway track, about 28 feet off the floor line, and put a pan under the track. We dump directly from the car into the pan, put a feeder under the pan, feeding into a cast iron chute at the upper end of the kiln, and discharging at the lower end into a steel elevator and from this to an overhead conveyor which discharges the burned clay into the dry pans in proper proportions with the raw clay.

This kiln, as I said, is 6 x 60 feet. It makes one to two revolutions a minute. We use a variable speed motor drive. It takes 15 h. p. to run the kiln and 10 h. p. to run the feeder.

We use fuel oil, and find that $7^1/_2$ gallons of fuel oil is used to produce a ton of clay. However, our temperature only goes to 1000° to 1200°F, as the nature of this clay is such that the shrinkage is practically taken out of it at that temperature.

The lining and the fuel, the clay supply, and the clay disposition after it is burned seem to me to be the governing factors rather than the rotary kiln itself, so it is just a question of getting these things lined up to accomplish whatever you start out after. As Mr. Austin suggests, each problem would have to be studied by itself, and proper arrangements made to meet these peculiar conditions in each particular installation.

Mr. GREAVES-WALKER:—Mr. McDowell, your Company, I believe, has attempted to use shaft kilns at some plant in Pennsylvania for calcining clays? Have you any information you could give the gentlemen on the method?

MR. MCDOWELL:—That method was not applied by us on plastic clays.

MR. GREAVES-WALKER:—I think the same thing would apply. The difficulty with most methods, either the rotary kiln or the others, is in handling finely-divided clay, that is the clay that is crushed down. Of course, in the rotary you crush it down, the smaller the better within certain limits, but I think the great question to everybody who has not used a shaft kiln, is how they can handle the fines, *i. e.*, whether they can use the kiln run of calcined clay or will have to separate the fines. Can you give us any information on that?

MR. MCDOWELL:—We used no fines in those kilns. The material fed into them is entirely clay lumps.

MR. CHRISTOPHER:—Our shaft kiln is fed directly from box cars, and discharges at the bottom from which we haul in trucks to cars. This kiln will hold three ordinary box car loads or about 140 to 175 tons of clay. We use lumps and do not use frozen clay for it would crack and all go to fine clay thus choking the kiln.

This kiln is about 28 to 30 feet high and about 14 feet inside diameter. We burn this 140 or 150 tons of clay to a red heat with coal. I have burned that kiln off with as low as 18 tons of coal.

MR. GREAVES-WALKER:—Mr. Christopher, can you not work that as a continuous kiln, merely taking it out at the bottom as you put it in the top?

MR. CHRISTOPHER:—I see no reason why it could not. Our kiln, however, was not built on piers. It was built on the ground.

There is no reason I know of, especially if you get choice flint clay, why you could not have the kiln right at the loading station along the railroads. In that case you could build the kiln on piers and have the firing platform above, much the same as with lime kilns. I rather believe McLean tried that at Rosewood.

MR. KRUSEN:—I believe he burned off something like 10 or 15 cars of clay altogether in that kiln, but he tried to use clay from the pit that was very plastic. It was not in big lumps. When they used large lumps they were rather successful, but his idea was to use clay from the pit. At that time nearly all the available clay was not in lumps but I think his plan was fairly successful for large lumps.

MR. SCHWETYE:—We haven't found any difficulty in calcining clay in a round down-draft kiln. When we use only lumps, we get a better draft, it will burn better, but you can use a certain percentage of fines.

MR. GREAVES-WALKER:—What is the fuel consumption?

MR. SCHWETYE:—Burning up to cone 12, the fuel consumption will run about one-half ton of coal to a ton of clay.

MR. CHRISTOPHER:—In calcining clay in a round down-draft kiln, the biggest coal saving that I know of is to be sure that your flue openings are open after your kiln is set. Our kilns have 40 to 50 square floor openings, each of which opening is covered with three flat tiles, three high. On top of these tile we set a 9″ round refractory tile similar to a chimney tile. After everything is set we take a long iron rod and spread the tile directly over floor opening so as to allow proper draft.

These floor tile on the bottom must be properly spaced and the clay punched out of them. In that way we can save about 40% of our fuel. I find that you can save more coal and more time with an hour's work in that way than you can in any other.

MR. GEIGER:—I should like to ask two questions, first as to handling of block plastic clay in calcining and what the cost per ton is for firing plastic clay to cone 12, regardless of the method and regardless of the treatment given it beforehand.

MR. GREAVES-WALKER:—Mr. Talbot, you have had some experience in running out fire clay into blocks.

MR. TALBOT:—In our experience, we found that it is better to grind the clay, then form and set them just as we do brick. If I remember correctly, it used to run around 1600 pounds of coal to the 1000 brick. This made the yield about $3^1/_2$ tons of clay to the ton of coal.

DISCUSSION[1] ON "MECHANICAL METHODS FROM CLAY BANK TO MACHINE"

MR. TEFFT:—This is a subject we are all interested in because there is such an opportunity to improve most of our plants with labor-saving devices. While it is impossible to apply the same remedy for correction of costly clay gathering apparatus to each plant I am sure that a general discussion now will bring out certain methods that can be applied in most cases.

MR. LANGWORTHY:—It is rather difficult to participate in a discussion of this sort as there are so many different methods that are satisfactory depending upon the actual problem. It is my judgment that each individual case must be studied before a definite plan for handling the clay can be made up.

A MEMBER:—I want to put in a system of some kind to get the clay from our shale pits into the plant. I am figuring on belt conveyors and in one place in our plant, we have a "button" conveyor that is about 60 or 70 feet long which works very satisfactorily. I should like to know where anyone has used the "button" conveyor. What I have reference to is a wire cable operating in a trough, this cable being equipped with metal buttons spaced short distances apart.

In my case, I think they are 14 inches apart with 6- or 8-inch buttons. This operates very satisfactorily in a small way. If the clay is a little bit wet the buttons or the cable will ride on top of the clay, but if a hump is put in there is no trouble.

I once discovered one of the men riding this conveyor to hold the cable down. The clay will stick in the bottom and the button will creep up over it if it is not forced down or have a hump over which to travel.

MR. SMITH:—Do you put that hump in there in order to force the buttons to the bottom of the trough that they run in?

A MEMBER:—Yes.

MR. SMITH:—You are then building up friction against which you are pulling.

MR. BROWN:—I have had experience with "drag conveyors." There is a conveyor in which the belt is supported underneath by means of boards or metal plates instead of rollers and contrary to all expectations, they

[1] Heavy Clay Products Division, St. Louis Meeting, February, 1922.

have given excellent service and proved to be durable. It is obvious that they must consume more power than when the belt is supported on rollers, especially if the roller axles are provided with good bearings.

I have supplied the metal parts for "drag conveyors" at various times under protest and witnessed them in operation in various lengths to 80 and 90 feet long and was surprised to find them giving satisfactory results over a long period of time.

As compared to a conveyor having the belt supported by concentrating or troughing rolls, I am certain the latter will show a decided saving in power.

MR. TEFFT:—If the distance is not extreme I believe a belt conveyor is more satisfactory for most conditions than any other installation unless it is applied to a place where either the discharge end or the feeding end is a movable proposition. In such a case I believe you would spend more money on the conveyor to keep up with these moves than you would get out of it while it is in operation.

MR. BROWN:—I am not a clay worker but an engineer specializing in clay working machinery and in our practise, we have found that for comparatively short distances and with dry material the "button" conveyor will work successfully. We have tried to improve the belt conveyor as this type requires less power and when correctly built, will outlast the "button" type of conveyor and has greater capacity. It will work in short lengths or in long lengths up to several hundred feet long.

For handling waste clay in the machine room where the particles of clay are wet and surfaces somewhat oily from passing through a cutter, a flat belt conveyor is generally most satisfactory. In the storage shed and when handling raw clay, it is best to use concentrating or troughing rolls under the belt to prevent material from falling over the edge of the belt.

These rolls should be equipped with good self-oiling bearings, something that will not require frequent attention and will keep the bearings properly lubricated and exclude dirt.

With a properly designed and built belt conveyor, the installation will work continuously for years with a minimum of expense and attention. With the addition of a tripper, it can be made to discharge at any point along its length.

MR. TEFFT:—Our experience has been the same as Mr. Brown's. We have in our Milton Plant a 20-in. wide belt conveyor that is 115 feet long and another one that is about 150 feet long. They are, of course, under cover so that the belt is protected from the weather. With this protection we find that these belts will last several years.

I know one of the belts that we only recently took off had been on there for seven years.

We find however that where the loading point is changing it is very hard to beat a locomotive with cars. The conveyor is all right if you have the right type of shale planer, *i. e.*, one that works on a pivot and does not have to travel back and forth across a long face. Is that the type you have?

A MEMBER:—Yes.

MR. TEFFT:—We are using an Arbuckle type cutting a face about 300 feet long. We feel that it would cost us more to get conveyors up to the machine and keep them traveling with it at successive moves of the planer into the hill than it would to put the clay in cars and pull them with a locomotive. Mr. Smith, I believe you said your experience was the same.

MR. SMITH:—Yes, that has been my experience. We have another plant where our clay pit lies directly below the clay shed. There we use the truck car. This is an ideal condition. It is an illustration of the point that you must base each problem on its merits and settle it according to what you find.

MR. BROWN:—It is customary in a lot of plants to bring the clay up to the foot of an incline by means of a locomotive or a horse and then elevate it by means of a winding drum. A lot of these plants by making their incline longer could take it all of the way with their locomotives and save two or three men in that way. The hauls generally are short and you could extend the tramway back toward the pit so as to make the haul the entire distance by means of a light locomotive. There are many gasoline-driven locomotives that are more economical to operate than a steam locomotive.

The steam locomotive generally is heavier and should haul longer trains, that is, more cars, but you can haul enough generally with a three-ton or a four-ton locomotive and you can make your tramway heavy enough to carry that locomotive and three cars. You can also save the winding drum and the men required to operate it, and I think that in changing or designing a plant in the future, that should be taken into consideration because you want to save as many men as you can.

MR. SMITH:—Mr. Brown, what do you consider the maximum grade that is economical for operating a locomotive as compared with the winding drum?

MR. BROWN:—An 8% grade is supposed to be the maximum at which they can be operated successfully. They do not really work to advantage on steeper grades.

MR. SMITH:—With a train of four yard cars what would you consider the maximum grade one of the locomotives would climb efficiently and economically?

MR. BROWN:—I am not advertising our locomotive. Any locomotive

could haul one-fourth its own weight, that is, the draw-bar pull should be one-fourth its own weight, and the draw-bar required to move a ton of material is something like thirty pounds, and then for every 1% of grade incline twenty more pounds would be added, making thirty pounds. For instance, if you have an 8% grade, that is 160 pounds plus 30, making 190 pounds draw-bar pull required to haul a ton up that incline. The weight of the locomotive in that case was five thousand pounds from $^1/_5$ to $^1/_4$ the weight of the locomotive would be your draw-bar pull under these conditions. An 8% grade is a rather difficult grade for a locomotive, since they do not hold to the tracks as well as on the level ground.

The above are approximate figures only as each case must be regarded as an individual case.

A good idea of what is possible may be had when I tell you that on a straight and level track, with cars equipped with a high grade of ball or roller bearings in good order and properly lubricated, seven pounds draw-bar pull will move one ton and that in practice, from 20 to 60 pounds draw-bar pull is required to move one ton.

Therefore, it would seem to me that we are not giving sufficient attention to certain details such as grades, curves, weight of rails, condition of road bed, condition of cars, etc. as there is an opportunity for saving power and wear and tear all along the line whether you use a horse, winding drum, a locomotive or any combination of these.

A MEMBER:—We are doing what Mr. Brown has suggested by pulling our clay in with the locomotive. We get the locomotive behind the loads. We carry three-, four- or six-yard dump cars. From the block down to the by-pass track it is about 250 feet, and $7^1/_2$% grade.

A run is necessary at that grade, especially if the track is wet. We allow our empty cars to drop to the pit by gravity and these by-pass.

MR. BROWN:—What size locomotive have you?

A MEMBER:—Ten by sixteen, steam locomotive.

Mr. STEVENS:—In connection with the general problem of the most economical way to transport raw materials to the plant, I think the most striking example of efficiency along that line that I have ever seen is of the Streator Brick Company at Streator, Illinois.

They use the large drag line, a Marion, it is called, a large-sized machine, and an extensive installation. The drag line is located on top of the shale bank, and they bring the shale up to the top of the bank to load the cars. The top of the bank is higher than the level of the plant, consequently the loaded cars go to the plant by gravity and then a special differential hoist arrangement is used whereby the pull of the loaded cars helps to pull the exemption back up. A drum will boost them along if this is not sufficient, but to a very considerable extent the gravity force of the loaded cars pull the empties back.

MR. TEFFT:—That is another example where it pays to study the peculiar situation that you have before you.

MR. POTTS:—I do not know anything about Mr. Vincent's conditions but it seems to me that a light locomotive and cars would put the clay in cheaper than the belt conveyor.

We have been using a locomotive made out of a Ford engine made by the Parkville Truck Company, costing less than $1500. That handles the car over an 8% grade without any trouble and the maintenance on it is very low; it takes about 4 to 5 gallons of gas a day, and probably takes between a pint and a half and a quart of oil—lubrication oil. One man can run it, and that man dumps his own car when he gets into the plant.

As I remember the conditions there, the bank is higher than the clay shed, and you are practically downgrade, or on the level with the loading. When we bought the locomotive we expected to have the same conditions but we discovered we had a drop there and that put us a little below our plant. I think you could buy the locomotive and cars for less than it would cost you for the best conveyor and the maintenance would not be much.

DISCUSSION ON "TENTATIVE SPECIFICATIONS FOR GLASS HOUSE REFRACTORIES"[1]

MR. ROSS:—During the year the Standards Committee of the Glass Division has been asked to prepare tentative specifications on lime for use in glass and on refractories for use in the glass industry. As Mr. A. E. Williams is particularly familiar with the specifications on lime, I have suggested that he take them in charge when they come up for discussion.

As to the Standard Specifications for Glass Industries Refractories, my personal opinion, after having worked with this matter for the last two and one-half years, is that our present knowledge of this subject is entirely too meager to permit of us drawing up satisfactory Standard Specifications at this time. I further believe that the present Committee's report might well serve as a basis for discussion at this meeting, which discussion may be of value to future committees dealing with Glass Industries' Refractories.

In conclusion, it appears to me that what we need now is more research along these lines and no final Standard Specifications except as each point is thoroughly proved out and that in this way injustice to any and all can be avoided.

The Committee's Report on Glass Industries Refractories follows:

[1] Glass Division, St. Louis Meeting, February 28, 1922.

REPORT OF COMMITTEE ON GLASS INDUSTRIES REFRACTORIES

Introduction

The effort of this Committee has been to develop a set of specifications that will aid the consumer in getting what he needs, and then obtaining the most service from what he gets, and at the same time to be a guide to the manufacturer in supplying it, without working a hardship on either. We believe that such a set of specifications, when ultimately worked out with proper limits, should even be an aid to the manufacturer in producing better grades of refractory wares.

Our aim has been to obtain limits that actually apply to the wares as now made, where possible pointing the way to better practice, and where it is necessary to apply tests, having them of such a nature that the results will distinguish clearly between satisfactory and unsatisfactory products. At the same time, knowing that a large percentage of the plants manufacturing and using these products are still unequipped with laboratories, it has been our aim to have all tests so arranged that they can be applied on any plant without special laboratory equipment. This has been done to permit of ready application of the specifications under existing conditions.

In so far as they apply the committee has endeavored to use the A.S.T.M. specifications for refractories, notably the reports of Committee C-8. However, there are several requirements that are essential to refractories used in the glass industries, that are of minor importance to refractories used in other industries. Hence it has been necessary to devise several more or less new tests. These have been worked out by observing the peculiarities of the various wares in service, and then selecting from the mass of laboratory tests on hand those which most clearly delimit (prescribe the limits of) the particular requirements under consideration.

The specifications herein set forth are of necessity of a tentative nature. We believe that the general plan will prove satisfactory, but that a great deal of thought must yet be given to the subject, and considerably more data be collected relative to proper limits, etc., before these tentative specifications can all be accepted as standard.

Many of the limits are already quite well established, while others need more weight of evidence.

Heat treatments are expressed in cone numbers, the temperature measuring instrument being depended upon merely to indicate the progress of the furnace. It is preferable however to use accurately calibrated instruments and record exact temperatures in addition to the cone numbers.

An effort has been made to correlate all the tests and their limits, so that one specification will not conflict with another.

It appears very desirable to have a hot bending test for pot clay at

glass melting temperatures, which in a measure at least will correspond to the bulging of pot walls. It also appears desirable to have a test which in a measure corresponds to the shrinkage that takes place in the pot while it is in the pot arch, and the additional shrinkage which must take place before the pot can be considered to be in a satisfactory condition for use.

The limits, etc., of the load test have been so thoroughly worked out that we believe there will be no need to alter them in the future. Hence, the results of such tests may well form a basis for correlation of other tests. 1 (*b*) and (*d*) have been worked out for use in lieu of the load test, where a load test furnace is not available.

Under Clay Refractory Blocks and Bricks, for Class A materials, the limits correspond to those usually used for first grade clay refractories, while for Class B materials, the limits include what are generally considered as second and third grade clay refractories. The limits of this test have been quite thoroughly worked out and correlated with results of the load test.

The limits, etc., for the hot bending tests and for volume change of pot clay during firing are not as thoroughly worked out as we hope to see them later.

Specifications

1. **Clay Refractory Blocks and Brick.—Class A:** Materials which are intended to be exposed to the direct heat of the furnace and to be either subject to the action of dust or not, but not to be in contact with the glass itself.

(*a*) These materials (cut to the form of standard 9-inch brick) when subjected to a load of 40 pounds per square inch, and heated as follows, in the usual form of load test furnace:

Time	Temp. °C	Time	Temp. °C
0 hr.	0.0	3 hrs.	1200
½ hr.	370.0	3½ hrs.	1270
1 hr.	670	4 hrs.	1320
1½ hrs.	880	4½ hrs.	1350
2 hrs.	1020	5 hrs.	1350
2½ hrs.	1120	5½ hrs.	1350
		6 hrs.	1350

Bricks so tested shall not yield in compression more than 4% (measurement to be made on cold brick after test).

(*b*) In the case of aluminous material the softening point[1] should not be less than that of cone 31 and pieces cut (or moulded) to form standard 9-inch brick on being heated to 1400°C (2555°F) in 4 hours and held at that temperature for 5 hours, shall not expand more than 1%, nor con-

[1] U. S. Bureau of Standards, *Tech. Paper* **7**, also see method of No. 1 below.

tract more than 1.5% linear. Not many people keep their thermocouples accurately calibrated, hence in lieu of the above test we suggest that cone 15 be brought down in 4 hours and that this temperature be maintained for 5 hours by means of a thermocouple which will indicate the progress of the test furnace but which need not be calibrated to indicate the true temperature.

In the case of siliceous brick the softening point may be as low as cone 28, provided the compression in the load test, as described above, is less than 3%.

(*c*) Bars 3 x $1^1/_2$ x 12″ made of the raw refractory batch and fired in a commercial kiln with refractory blocks, when supported on knife edges (10-inch span) loaded at the center (M = 10 pounds per square inch) and heated in a test kiln to cone 15 (cone 15 in 6 hours and held at this temperature one and one-half hours) shall not sag on the under side more than $^1/_2$ inch below the knife edges.

Class B: Clay Refractories which are not directly exposed to fire or glass attack (such as materials used in backing up).

(*d*) These clay refractories should have softening points between cones 26 and 31. The limits shall be the same as for first grade refractories above when a standard 9-inch brick sized piece is heated to 1270°C (cone 12) in 4 hours and held at that temperature for 5 hours.

In lieu of a calibrated thermocouple we suggest that cone 12 be brought down in 4 hours and that this temperature be maintained for 5 hours.

(*e*) Dimensions of all materials in A and B must not vary more than $^3/_{16}$-inch per foot from specified dimensions. Bricks and blocks in both classes must be reasonably well made and correspondingly free from drying and burning defects, such as cracking, warpage and improper oxidation.

Silica Refractories.— (*a*) Silica brick and tile should have a good ring.

(*b*) In order to insure satisfactory quartz, cristobalite, tridymite relations, the specific gravity[1] should not be over 2.38 for brick made from Medina quartzite, nor more than 2.42 for brick made from Baraboo quartzite.

(*c*) The effective modulus[2] of rupture of standard 9-inch brick, set on edge on knife (6-inch span) should not be less than 500 pounds per square inch.

(*d*) The softening point[3] shall not be less than that of cone 31.

3. Flux Blocks.—(*a*) The softening point[1] determined on cones made from a ground sample (60-mesh) of the block, shall not be less than that of cone 29.

(*b*) The porosity[4] of tank blocks shall not be over 25%.

[1] See method 2 below.
[2] See method 3 below.
[3] See method 1 below.
[4] See method 4 below.

(*c*) Crucibles made of the raw flux block mixture, in a mould as per the accompanying sketch, fired in a commercial kiln with flux blocks (or optical to cone 12 in a test furnace in 6 hours and held one and one-half hours) and subjected to a three day fluxing test at the temperature and with the glass (cullet) against which the blocks are to be used, shall show but little attack. The amount of attack can be observed either by cooling the crucible with the glass in it and splitting the crucible vertically through its center, or by pouring the hot glass and inverting the crucible in the furnace for a few minutes to drain. It can then be studied without being broken.

(*d*) The porosity of $2^1/_2$-inch cubes cut from fired blocks and reheated in a test kiln (1400°C in 6 hours (2555°F) and held at that temperature for one and a half hours) shall not have a porosity greater than 22%, nor less than 12%. The volume change determined by suspended weight method[1] shall not exceed 6%, nor be more than 1% expansion. In lieu of a standardized thermo element, we suggest cone 15 in 6 hours and that this temperature be maintained for 1.5 hours.

(*e*) The requirements for dimensions, etc., shall be the same as for 1 (*e*). Rectangular blocks shall be truly so and not merely have opposite sides parallel.

4. Glass Melting Pots.—(*a*) The softening point[2] determined from cones made of the raw pot mix, when ground to pass a 65-mesh sieve, shall not be less than that of cone 30, and the softening point of any individual plastic clay constituents of the mix, similarly treated shall not be less than that of cone 29.

(*b*) Bars 1 x 1 x 7″ made from raw pot body, and fired in a test furnace to cone 15 (cone 15 in 6 hours and held at this temperature for 1.5 hours) when supported on knife edges (5-inch span) loaded at the center (M = 7 pounds per square inch) and reheated in a test furnace to cone 15 the same as they were the first time, shall not sag (measured on the under side) more than one-half inch below the knife edges.

(*c*) The total shrinkage[3] of the pot mix from the wet raw state (consistency of side clay) to the condition after being fired to cone 14 in a test furnace (cone 14) in 6 hours and held at this temperature (1.5) hours shall not be over 24% (approximately) by volume (3% linear) based on per cent of wet size. The shrinkage between cone 4 and 14 (determined on pieces previously burned to cone 4), when heated same as above, shall not be more than 3.9% (approximately) by volume (1.3% linear). These figures are based on a drying shrinkage of 15% (approximately) by volume (5% linear) and a burning shrinkage to cone 4 of 5.1% (approximately) by volume (1.7% linear).

[1] See method 5 below.

[2] See method 1 below.

[3] See method 5 below.

(*d*) Bars 1 x 1 x 7″ made of the raw pot mix, when dried and broken according to the tentative method of the AMERICAN CERAMIC SOCIETY[1] shall not show a modulus of rupture less than 225 pounds per square inch.

Any material failing in any one test shall be discarded as unsatisfactory.

Methods of Procedure

1. Softening Point.—The sample shall be ground to pass through a 65-mesh Tyler Standard Screen (0.208 mm.) mixed with water and molded into cones similar to Seger-Orton pyrometric cones (tetrahedra, 7 mm. along an edge of the base and 30 mm. high). If the sample be non-plastic, a little organic glue may be added, so that the cones will hold together when dry. The cones shall be set in a straight line in a plaque. A dried cone of the sample shall be set in the plaque with not more than 2 Orton cones on each side of it. Thus none of the standard cones need be more than $^3/_4$ inches away from the material being tested. The heating shall be done in a gas-fired or other furnace in which the atmosphere is maintained nearly neutral (not strongly reducing). The total period of heating shall not be over 2 hours. The rate of heating, near the softening point of the material, should not be greater than that required to cause the bending of one standard cone in 3 minutes.

2. Specific Gravity of Silica Brick.—$2^1/_2$-inch cubes of the dried material are weighed, saturated with water and weighed wet, then weighed suspended in water. In terms of grams and cubic centimeters the specific gravity $= \dfrac{D}{(W-S)-(W-D)}$ where D = dry weight, W = wet weight (saturated weight) and S = suspended weight.

3. Effective Modulus of Rupture.—The effective modulus of rupture is obtained by subtracting the average deviation from the mean modulus of rupture. The average for this figure shall be made from data on not less than six bricks. The modulus of rupture is calculated by means of the following formula: $R = \dfrac{3WL}{2bd^2}$, where R equals modulus of rupture, L equals distance between supports in inches, b equals breadth of specimen in inches, d equals depth of specimen in inches, and W equals load in pounds at which failure occurs. The mean modulus is merely the arithmetical mean of these figures, and for the effective modulus we have: Effective R = mean $R = \sqrt{\dfrac{S}{N-1}}$, where S equals the sum of the squares of the differences between the various observations and the mean modulus, and N equals the number of observations.

[1] Report of Committee on Standards, Jan. 3, 1918, pages 40–43.

4. Porosity of Burned Clay Products.—$2^1/_2$-inch cubes of the dry material are weighed, saturated with water and weighed wet, then weighed suspended in water. Then, in terms of grams and cubic centimeters, the porosity (ratio of the volume of the open pores to the exterior volume of the piece) $= \frac{W-D}{W-S}$, where D = dry weight, W = wet weight (saturated weight), and S = suspended weight.

5. Volume Change by Suspended Weight Method.—$2^1/_2$-inch cubes of the material are saturated with water and weighed wet, then weighed suspended in water, after which they are dried and reheated. Saturated and suspended weights of the reheated pieces are taken. The volume change $= 1 - \frac{W_2S_2}{W_1S_1}$, where W_1 = wet weight (saturated weight) before reheating, S_1 = suspended before reheating. W_2 = wet weight (saturated weight) after reheating and S_2 = suspended weight after reheating.

If it is desired to measure the change in volume from the raw to the fired state, the pieces may be run in oil both before and after firing. Or if run in water after firing, the readings in oil must be converted to a water basis by dividing by the specific gravity of the oil as: $\frac{W_1-S_1}{\text{sp. gr. of oil}}$.

Addendum

As soon as possible data should be obtained for a heating schedule to be used in heating glass melting tanks. At present we can only suggest the following:

In days 1–75°C (167°F); 2–120°C (248°F); 3–234°C (450°F); then 94°C (200°F) per day to 1250°C (2300°F). In heating window glass tank blocks for hot repairs the same schedule is suggested to 900°C (1657°F), then hold for 36 hours.

The present specifications as far as pots are concerned deal only with the constituents from which the pots are made. It is hoped however that we may soon be able to outline a standard method of handling pots by the consumer, and of their preparation for the furnace.

At present we can only suggest that pots, tank blocks, refractories, etc., stored by consumers, be kept above 90°F (32°C) at all times.

With pots which have been stored as above, the following heating schedule is suggested.

In days 1–75°C (167°F); 2–120°C (248°F); 3–371°C (700°F); 4–596°C (1110°F); 5–816°C (1500°F); 6–1025°C (1880°F); 7–1160°C (2120°F); (check with cone 4 flat under center of bottom) 1 hold 30 hours.

The pot arch should be cooled to 32°C (90°F) before pots are placed in it. If a pot arch is cold it should be dried out by heating to redness

and then cooling to 32°C (90°F) before pots are placed in it. Where pots are to be set directly in a pot furnace at time of starting up, the furnace should first be dried out by heating to bright redness and then cooled to 32°C (90°F) before the pots are placed in it.

It is essential that the pot arches be constructed so that the bottoms of the pots will be as thoroughly heated as the crowns. Pot arches of the down draft type, with exit flues directly under the center of the pot, largely aid in obtaining this uniformity of heating throughout the pot. In easily applied check on the uniformity of heating in the pot arch is to place one pot of cones under the center of the bottom of the pot, and a similar set on top of the crown, cones 01 to 5 inclusive usually serve for this purpose. It may even be desirable to go much higher than above suggested.

It is desired to establish as soon as possible, a fluxing test for pot clay, of the same general nature as that given for flux clay.

DONALD W. ROSS, *Chairman*
GEORGE A. LOOMIS
ARTHUR F. GORTON
C. W. BERRY

MR. HOSTETTER:—You have heard these recommendations and comments of our Committee. It seems to me we may well discuss them, not in their entirety, but separately. We could possibly take the items, "Glass Melting Pots," "Flux Blocks and Clay Refractory Blocks and Bricks and "Silica Refractories." The Committee speaks of cone 27. I have asked the different men what it meant. The answers varied 1670°C, 1620°C, and 1650°C. Cone 27 means something to some of the members but the temperature in Fahrenheit would mean more to the rest of us.

DOCTOR WASHBURN:—A paper is to be presented on this subject by Mr. Sieurin.[1] It gives some very interesting results which seem to point in the near future to being able to replace fusion point specifications and load specifications by chemical composition specifications and porosity.

MR. GRAFTON:—I am sure the clay pot and tank block manufacturers wish to coöperate in every way with the Glass Division in arriving at the standardization of these products, but we do not think it is advisable to adopt any particular standard until the matter is more fully considered.

This test calls for a fusion test of cone 27 to 28, and a softening point between cone 29 and 30, which is 3000°F. That is a pretty high test for some of our clays. Some of the clays we use will not stand that test.

The Gross-Almerode clay would not stand at cone 26. The glass manufacturer is demanding that his product be made from German clay. If these specifications are adopted, it would practically eliminate the use of German clay in our product. We are all trying to find a batch that will

[1] Sieurin and Carlsson, "Resistance Tests on Fire Bricks under Loads at High Temperatures," *Jour. Amer. Ceram. Soc.*, **5**, 170 (1922).

give longer life to the tanks and pots and while some may feel that our domestic clay is superior to the German clay, a great many believe that the German clay is better.

The clay pot manufacturers have recently appointed a committee on this subject, and they would be willing to ask that committee to act in connection with a committee of the Glass Division. The two parties could consult with Committee C-8 of the A.S.T.M.

I move that we adopt that part of the report of the Committee which states that in view of the limited data available our Committee considers it inadvisable to propose a large number of tentative specifications for glass house refractories until the question has been given a more practical study. I also move that a committee be appointed from this Division to consult and confer with the Committee C-8 of the A.S.T.M.

MR. BROWN:—Mr. Chairman, I second that motion.

MR. HOSTETTER:—You have heard the motion and it has been seconded. Dr. Silverman states "If our recommendations are approved by the Glass Division, we suggest that they be submitted to the General Committee on Standards of the AMERICAN CERAMIC SOCIETY for their consideration and for final approval by the SOCIETY at large." This is one of the duties of the Committee of the AMERICAN CERAMIC SOCIETY to confer with the Committee of the A.S.T.M.

MR. ROSS:—Some time ago, when this matter first came up, arrangements for a conference with the A.S.T.M. were started, but it has not been held, as I understand the A.S.T.M. Committee has not yet been assembled.

MR. BROWN:—When that Committee, of which I am a member, was appointed a year ago, I wrote to Doctor Silverman, that some of us knew absolutely nothing of specific facts about glass house refractories. On the other hand, we had men who were experts who did not have data available on matters such as lime. The same Committee had to handle both specifications, and in my case I could do nothing in the question of refractories. Lime and other glass house raw material should be considered by a separate committee. We have in our factory several grades, in which, used by another company, the specifications set by Mr. Williams made it questionable. This Refractory Committee has done good work, but I think the motion as made and seconded is right and the matter should be further considered.

DOCTOR WEBB:—Mr. Grafton has told us one possible effect which the adoption of one of these specifications might mean to the manufacturer. Would it not be well, by means of a questionnaire to find out how all of them would be affected should it be adopted, and have that available for the Committee?

MR. GRAFTON:—A communication was received from Secretary Purdy.

It was requested that the clay pot and clay manufacturers appoint a committee to work in connection with Dr. Silverman's committee.

MR. HOSTETTER:—These specifications, as proposed, are not entirely satisfactory, even as tentative specifications, but personally I should like to see the Committee working on one subject, reduced to a minimum. Now, whether the report should be referred back to the Committee on Standards, expressing the sentiment that we didn't consider the job as having been fairly done and suggesting a questionnaire to the glass house refractory men, or whether we should appoint an additional committee is the point I have in mind.

MR. ROSS:—There is a Standards Committee in our Division, and that Committee will have this matter in charge as far as the Glass Division, the membership of which is appointed each year for one year of service, is concerned.

MR. BROWN:—The matter has been pretty well discussed and three members of the Committee are here; the first part of the report is in two parts (1) refractories and (2) lime specifications. Mr. Grafton has made a motion which has been accepted not to accept the report as turned in, but only part of it. If that is put to a vote, we can dispose of that and then go to the lime which will be accepted probably, and then the committee can be discharged and you can appoint a new committee, one to handle refractories and the one raw materials.

(The motion was carried.)

DISCUSSION ON "ELIMINATION OF STREAKS IN WHITE OPAQUE GLASS"

MR. HOSTETTER, CHAIRMAN:—When I read this title I wondered whether the gentleman who proposed it has in mind glass that is to be (1) blown or (2) cast and rolled, or (3) pressed in small units. Certainly the three types of working require substantially three different types of glass.

MR. PAYNE:—Dealing with the third type, you can eliminate streaks by using a substitute of small articles to be pressed. We probably have made as much opaque ware as anybody in the country. I cannot tell you how to eliminate streaks, but I can tell you of the things that cause them. We run ordinarily 250°F in our opal vats, and 50° excess heat will cause a tremendous number of streaks. We get some with flint glass mixed in. It is more or less transparent and shows dark, and there may be some gas or crystal that will cause it as well. It can easily be done when we make a shift from natural gas to oil, or the other way round.

ACTIVITIES OF THE SOCIETIES

BREAKING INTO THE MOVIES

The sporty editor of the BULLETIN always tries to be seasonable.....

This month while the wind blue chill the members of the SOCIETY have been practicing that popular pastime known as ski-jumping. Fifty-five, donning their moccasins and earmuffs (over their custom-mades), entered into this blood-warming exercise, and may now be seen at any movie on Tuesday or Saturday nights. Those with long legs have a natural advantage of course, but this should not be allowed to discount the work of Charles A. Smith, of Columbus, who made leap after leap until he lep clear off the end of the slide and the tape of the judges gave out entirely. He ended at least thirty feet in advance of his nearest competitor, R. R. Danielson of Ellwood City, Pa., who is hardly in the long-legged class but nevertheless was thirty feet ahead of the next man. D. F. Albery, of Chicago, and Alexander Silverman, of Pittsburgh, tied for third place.

Ira E. Sproat, the tallest man in captivity (at least we think he's married), after three classic leaps, did a tail spin that brought home the real bacon in the form of a Corporation Member. Four charter members threw their dignity over the fence and showed the youngsters where to head in, by doing similar stunts, each bringing in a Corporation Member. These were F. W. Walker, S. Geijsbeek, Edward Orton, Jr., and H. C. Mueller. E. C. Sullivan, V. A. Giesey, H. F. Kleinfeldt, and W. H. Herbert followed suit. The score card follows:

	Personal	Corporation		Personal	Corporation
Charles A. Smith	11		J. W. Cruikshank	1	
R. R. Danielson	8		R. V. Widemann	1	
D. F. Albery	5		W. E. Dornbach	1	
Alexander Silverman	5		F. H. Auld	1	
Ira E. Sproat	3	1	A. V. Bleininger	1	
R. K. Hursh	3		Miss Mary G. Sheerer	1	
P. H. Swalm	2		Miss Mabel C. Farren	1	
R. F. Segsworth	2		C. H. Modes	1	
E. W. Tillotson	2		Joseph A. Martz	1	
A. Malinovzsky	2		E. H. Fritz	1	
T. W. Garve	2		D. A. Moulton	1	
F. W. Walker		1	E. A. Brockman	1	
S. Geijsbeek		1	F. C. Flint	1	
Edward Orton, Jr.		1	K. N. Endell	1	
H. C. Mueller		1	A. E. Williams	1	
E. C. Sullivan		1	F. K. Pence	1	
V. A. Giesey		1	D. M. Thorpe	1	
W. H. Herbert		1	Chas. A. Nicely	1	
H. F. Kleinfeldt		1	Leon J. Frost	1	
H. S. Langworthy	1	1	Charles F. Geiger	1	
A. O. Austin	1		Leslie Brown	1	
C. F. Binns	1		Wm. Cannan, Jr.	1	
F. H. Rhead	1		J. S. McDowell	1	
G. Percy Cole	1		W. M. Jacobs	1	
P. H. Walker	1		Charles G. Lippert	1	
C. E. Bales	1		Edmund Brown	1	
W. F. Wenning	1		A. Weber, Jr.	1	
R. E. Griffith	1		Office	29	

Total 110 Personal, 10 Corporation

H. S. Langworthy made a clever jump and swung around the circle with a Corporation Member hanging to his coonskin cap. R. K. Hursh made three jumps of great brilliance, while P. H. Swalm, R. F. Segsworth, E. W. Tillotson, A. Malinovzsky and T. W. Garve each made two. Of course it was comparatively easy for a Canadian but how they do it in California is something for Mr. Einstein to explain. Thirty "also-entereds," among them two of our better halves, did themselves and the Society credit without receiving a D. S. O. for it.

What really makes this ski-meet a gala occasion is that the total jumps of all the participants put the SOCIETY ahead of where it was at last reports by one hundred and twenty members. The dizzy total now is 1918. Don't be mistaken. This is not a year, nor a time for the 220; it is the actual number of members now belonging to the AMERICAN CERAMIC SOCIETY.

NEW MEMBERS RECEIVED FROM JAN. 13, 1923 TO FEB. 10, 1923

ASSOCIATE

Adcock, Albert Scholl, 1999 Iuka Ave., Columbus, Ohio, Student Ceramic Engineering, O. S. U.

Arnold, Russell Ellsworth, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa., Ceramic Engineer.

Barnhart, Marion M., 225 W. Ohio Ave., Sebring, O., Gen. Supt. Limoges China Co.

Black, Thompson Wm., Oshawa, Ontario, Mgr. Ontario Potteries Co., Ltd.

Boyd, Robert C., Sigma Nu House, Ames, Iowa, Student.

Buck, L. M., Fort Ave. & Lawrence St., Baltimore, Md., Treas. The Buck Glass Co.,

Burket, Chester C., 1288 Nicholson Ave., Lakewood, Ohio, Secy. Cleveland Feldspar Co.

Burkhalter, Edward, 80 Thirteenth Ave., Columbus Ohio, Student.

Butman, Leo T., F. R. Muller & Co., Waukegan, Ill., Production & Factory Mgr.

Canfield, Ruth Ella, Instructor of Ceramics and Weaving, Carnegie Inst. of Technology, Pittsburgh, Pa.

Christman, H. M., 30 E. Frambes Ave., Columbus, Ohio, Student.

Cook, Herman L., 406 E. Healey St., Champaign, Ill., Student, Univ. of Illinois.

Cummings, John W., Box 16, Bath, Maine, Pres. & Treas. Mining & Grinding Feldspar.

DeVol, Arthur B., 34 Eighteenth Ave., Columbus, Ohio, Student.

DeVol, James Coleman, A-B Stove Co., Battle Creek, Mich., Supt. Enameling Division.

Dodge, Alfred W., Y. M. C. A., Zanesville, Ohio, Chemist, Kearns-Gorsuch Bottle Co.

Dorfner, Josef, Doktor Ingenieur, Meiningen y Thüringen (Deutschland) Direktor der Forschungs-Gesellschaft vereinigter Porzellanfabriken m.b.h.

Dunkin, Damon Duffield, Guion, Arkansas, Pres. & Gen. Mgr., Silica Products Co.

Dunwody, William Elliott, 460 Broadway, Macon, Georgia, Pres. Standard Brick Co.

Emmert, Edward, Des Moines, Iowa, Dist. Sales Manager, Walsh Fire Clay Products Co.

Gordon, Donald Dean, Wallaceburg, Ont., Mgr. Dominion Glass Co., Ltd., Wallaceburg Factory.

Gosnell, Jack, Washington Iron Works, Los Angeles, Calif., Charge of Mixing Room.

Gould, Robert E., 1927 Waldeck Ave., Columbus, Ohio, Student.

Hagar, I. D., 94 Fulton St., New York City, Buckman & Pritchard, Inc.

Hemsteger, Samuel E., 91 Sixteenth Ave., Columbus, Ohio, Student.

Higgins, Ray, 431 High St., Wadsworth, Ohio, Electrical Eng. Ohio Insulator Co., Barberton, Ohio.

Hobson, Mrs. George H., 126 High Street, Brookline, Mass.

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Jones, Edgar, 35 Rimbach Ave., Hammond, Ind.

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Koch, Edward, 655 Underhill St., Louisville, Ky., Standard Sanitary Mfg. Co.

Lampert, Walter G., 108 E. McComb St., Belvidere, Ill., Supt Hercules Porcelain Co.

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Leary, William H., 907 E. 75th St., Sec. & Treas., Pyrometer Engineering.

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Riviere, Georges, 98 Boulevard de Courcelles, Paris, Administrateur-Directeur de la Cie Gle de Construction de Fours.

Roy, Charles Smart, St. Helens, Forest View, Chingford, London, E. A., England, Chemical Technologist.

Smart, Richard Addison, 114 Colorado Ave., Detroit, Mich., Detroit Rep. American Refractories Co.

Totten, George Oakley, Jr., 808 Seventeenth St., Washington, D. C., Architect & Porcelain Manufacturer.

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Wehtje, Ernst, Bromölla, Sweden, Managing Director, Aktiebolaget Ifö Chamotte-Kaolinverk.

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Wishnew, Alex., Y. M. C. A., Wheeling, W. Va., Ceramist, Wheeling Tile Co.

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Edward Orton, Jr., 1738 N. High St., Columbus, Ohio.

WHO'S WHERE IN THE AMERICAN CERAMIC SOCIETY

P. S. Bachman, formerly of 92 W. Maynard Ave., Columbus, Ohio, is now located at 563 Market St., Wooster, Ohio.

C. E. Bales, Chemist of the Louisville Fire Brick Works, was recently elected President of the Louisville Section of the American Chemical Society.

Richard B. Carothers, Assistant Manager of the H. C. Spinks Clay Co., has moved to Puryear, Tenn., from Newport, Ky.

Conrad Dressler of the American Dressler Tunnel Kilns, Inc., has changed his address from 1740 East 12th St. to The Studio, 10915 Cedar Avenue, Cleveland, Ohio.

R. F. Ewing, formerly with the McLain Fire Brick Co. at Wellsville, Ohio, is now associated with the Globe Brick Co., E. Liverpool, Ohio.

Gerald Fitz-Gerald of Birmingham, England, informs us that he has accepted a position with the Maxon Furnace & Engineering Co., located at Muncie, Ind.

F. P. Hall with the U. S. Bureau of Standards, Washington, D. C., has moved from 630 Webster Ave. to 4717 Wisconsin Ave.

Max Meissner advises a change of address from Hoopeston, Ill., to 15200 Loomis Ave., Harvey, Ill.

Ichijo Mokiji of 165 Broadway, New York City, is now in Germany, care of the Japanese Consulate General.

Joseph K. Moore of 122 Waverly Place, New York City, announces his new location at Room 2602, 120 Broadway.

C. Nick Muessig, salesman for the B. F. Drakenfeld Co., Inc., has deserted his E. Liverpool, Ohio, address for 50 Murray St., New York, N. Y.

Henry Oesterle of Canandaigua, N. Y., is now connected with the Roesch Enamel Range Co., at Belleville, Ill.

George J. Openhym, a former student at the N. Y. State School of Clayworking & Ceramics, wishes to be addressed at 16 Woodland Place, White Plains, N. Y.

James G. Phillips of Piqua, Ohio, has recently moved to 116 S. Broadway, Middletown, Ohio.

David A. Raiff, Coshocton, Ohio, wants his mail addressed to 138 Park Ave.

Wallace C. Riddell has changed his address from Le Roy Avenue, Berkeley, Calif., to 2544 Buena Vista Way.

Oscar Scherer has moved from Columbus, Ohio, to 530 Oakdale Ave., Chicago, Ill.

Ramsay Skinner, Treas. of the Reeves and Skinner Mach. Co., St. Louis, Mo., notifies us of a change of address from 4471 Olive St., to 3458 Sidney St.

R. T. Stull recently of the Columbus Station, U. S. Bureau of Mines, is now located in Savannah, Ga., as Assistant Industrial Agent of the Central of Georgia Railroad Co.

B. T. Sweely has discontinued his services with the Cribben & Sexton Co. of Chicago, and is now associated with the Baltimore Enamel & Novelty Co., Box 34, Baltimore, Md.

R. S. Webb of the American Window Glass Co. at Belle Vernon, Pa., wishes to be addressed at Larimer P. O., Larimer, Pa.

OBITUARY

Lysle R. Kraus, Secretary of the Kraus Research Laboratories, Inc., died Tuesday, Feb. 6th, 1923 as the result of a railroad accident.

Mr. Kraus was born Nov. 21, 1893 at Cockeysville, Md., was graduated from Sparks Agricultural College in 1914, and was one of the founders of the Kraus Research Laboratories, Inc., and associated himself with the company in the capacity of Ceramic Engineer.

In the ceramic field, Mr. Kraus invented several processes for the plasticizing of clays and developed many bonding clays of exceptional values. His research work in refractories was very exhaustive—making many improvements over present day methods and producing several new refractory bases.

Mr. Kraus' sudden death will be felt as a severe loss in the ceramic field.

NOTES AND NEWS

PROBLEMS IN THE DETERMINATION OF PHYSICAL PROPERTIES

Research Problems for Theses

In preparing for publication the data on physical properties of chemical substances, the editorial staff of International Critical Tables will find from time to time that important physical properties of substances of technical and scientific importance are missing from the literature. As fast as we become aware of missing data of this character, it is our policy to formulate research problems covering such missing data and to endeavor to interest chemists and physicists in undertaking the necessary investigations to supply the required data.

Most of the research problems formulated in this way will be suitable for bachelors' or masters' theses and in a few instances topics sufficiently broad to be suitable for doctors' theses will also be available. Many of them will be suitable for experimental problems in the ordinary laboratory courses in physical chemistry and physics. Thus, for example, the laboratory experiment covering the determination of solubility might, to advantage, deal with substances whose solubility is needed but is unknown. The average of the determinations made by a class of students, while not as accurate and reliable as the determinations made by a skilled investigator, will nevertheless be very valuable when they constitute the only data available on the subject. Moreover, the average student will be more interested in a laboratory experiment the results of which are of actual value and worthy of publication than he would be in repeating for the nth time the measurement of a property of some system which has been measured many times before.

International Critical Tables will be glad to submit to interested instructors in universities and colleges lists of problems of this character and to advise as far as it can concerning suitable apparatus and methods of measurement. It may be possible also in some instances to secure moderate financial assistance to aid in the purchase of materials and apparatus for investigators interested in carrying out work of this character. The results of such work may be published by the investigator in any appropriate publication medium and they should also be reported in duplicate to the office of International Critical Tables on completion of the work.

A number of problems on the following subjects are available at the present date: Heats of combination; solid oxides; Fe compounds. Specific heats; brass; solid oxides; steels; oils and fats; petroleum products; metals; salts; Fe compounds; asphalts. Latent heats of fusion; brass; metals. Heat conductivity; steels. Latent heats of vaporization; petroleum products. Viscosities; industrial materials; solutions. Kinetics; rates of drying hydrolysis of industrial materials; catalysis; transpiration of moisture; biochemical. Strength; industrial materials. Thermal expansion; steels; Fe compounds. Freezing-point-solubility diagrams; salts; acids; metals in water; soaps. Boiling points; solutions. Solubility of gases; in molten metals; in water. Chemical equilibrium; dissociation pressures at 1600°C. Electrical conductivity; metals, refractories. Properties of colloidal systems; industrial materials. Vapor pressures; metals; solutions. Specific rotatory power; gliadin. Index of refraction; solids. Density; certain organic compounds; solutions. Flash points. Surface tensions; solutions.

INTERNATIONAL CRITICAL TABLES,
1701 Massachusetts Avenue, N. W.,
Washington, D. C.

DECEMBER 10, 1922

NEW REPORT ON OHIO CLAYS

The Geological Survey of Ohio under the direction of J. A. Bownocker in coöperation with the United States Bureau of Mines, Columbus Station, with R. T. Stull in charge, has a report nearly completed on the coal-formation or buff-burning clays of Ohio. In all 87 samples were tested; 28 from the Pottsville formation; 55 from the Allegheny; 2 from the Conemaugh; and 2 from the Monongahela. The range is from high-grade flint to low-grade plastic clays. The report includes a short history of the progress of the various branches of the ceramic industry as practised in Ohio; geological data regarding the extent and stratigraphy of each bed with a list of the factories using it, the physical properties of each sample by R. T. Stull, the complete chemical analysis of each sample by D. J. Demorest, and a microscopial examination of representative samples of each member by William J. McCaughey. The report will approximate 450 pages.

WILBUR STOUT

BUREAU OF STANDARDS PUBLICATIONS

TECHNOLOGIC PAPERS ON CERAMIC PRODUCTS ISSUED[1] BY BUREAU OF STANDARDS, WASHINGTON, D. C.

A[2]

10. The Melting Point of Fire Brick
31. Some Leadless Boro-silicate Glazes Maturing at about 1100°C
40. The Veritas Firing Rings
50. The Viscosity of Porcelain Bodies High in Feldspar
104. The Effect of Size of Grog in Fire Clay Bodies
105. Comparative Tests of Porcelain Laboratory Ware
111. The Compressive Strength of Large Brick Piers
120. Tests of Hollow Building Tile
124. Constitution and Microstructure of Silica Brick and Changes Involved through Repeated Burnings at High Temperatures
142. Materials and Methods Used in the Manufacture of Enameled Cast Iron Wares
144. Properties of American Bond Clays and their Use in Graphite Crucibles and Glass Pots
155. Cement for Spark Plug Electrodes
159. Porosity and Volume Changes of Clay Fire Bricks at Furnace Temperatures
196. High Fire Porcelain Glazes.

B[3]

7. Testing of Clay Refractories with Special Reference to their Load Carrying Abilities at Furnace Temperatures (15c)
21. The Dehydration of Clays (5c)
22. Effect of Overfiring upon the Structure of Clays (5c)
46. A Study of the Atterberg Plasticity Method (5c)
85. Manufacture and Properties of Sand-Lime Brick (5c)
107. Comparative Tests of Chemical Glassware (10c)
116. Silica Refractories—Factors Affecting their Quality and Methods of Testing the Raw Materials and Finished Ware (20c)
165. Enamels for Sheet Iron and Steel (15c)

[1] Issued April 6, 1922.

[2] Available for distribution by Bureau of Standards.

[3] For sale by Supt. of Documents, Government Printing Office, Washington, D. C. at prices given.

C[1]

1. Effect of Preliminary Heat Treatment upon the Drying of Clays
17. The Function of Time in the Vitrification of Clays
23. Technical Control of the Colloidal Matter of Clays
30. Viscosity of Porcelain Bodies
51. Use of Sodium Salts in the Purification of Clays and in the Casting Process
79. Properties of Some European Plastic Fire Clays
80. Constitution and Microstructure of Porcelain

Scientific Paper No. 212—Melting Point of Some Refractory Oxides.

CALENDAR OF CONVENTIONS

American Association of Flint and Lime Glass Mfrs.—April, 1923.
American Association of Ice & Refrigeration—Washington, D. C., probably March, 1923.
American Dental Trade Association—Spring Lake, N. J., June, 1923.
American Face Brick Association—First Week in December, 1923.
American Face Brick Association, Southern Group—West Baden, Ind., November, 1923.
American Foundrymen's Association—Cleveland, Ohio, April 30–May 3, 1923.
American Gas Association—October, 1923.
American Hotel Association of United States and Canada—San Francisco, April, 1923.
American Society for Testing Materials—Place not determined, June, 1923.
American Zinc Institute—St. Louis, Mo., May 7 and 8, 1923.
Association of Scientific Apparatus Makers of the United States of America—Washington, D. C., April 20, 1923.
Chamber of Commerce of the United States of America—New York City, May 8–10, 1923.
Clay Products Association—Chicago, Ill., Third Tuesday in each month.
Dental Manufacturers' Club of the United States—Spring Lake, N. J., June, 1923.
Fire Underwriters' Association of the Northwest—Chicago, Ill., October 17–18, 1923.
International Chamber of Commerce—Rome, Italy, Week of March 19, 1923.
Manufacturing Chemists' Association—New York, June, 1923.
National Association of Brass Manufacturers—March, 1923.
National Association of Manufacturers of Pressed and Blown Glassware—Pittsburgh, March 13, 1923.
National Association of Manufacturers of the United States—New York City, Week of May 14, 1923.
National Association of Stove Manufacturers—Richmond, Va., May 9, 1923.
National Association of Window Glass Manufacturers—Place and date not determined.
National Board of Fire Underwriters—New York, May 24, 1923.
National Bottle Manufacturers Association—Atlantic City, N. J., Last of April, 1923.
National Gas Appliance Manufacturers Exchange—Kansas City, Mo., May, 1923.
National Gas Association of America—Louisville, Ky., Spring, 1923.
National Paving Brick Manufacturers' Association, December, 1923.
National Gas Association of America—Louisville, Ky., April 23–24, 1923.
Refractories Manufacturers' Association—March 21, 1923.
Sanitary Potters' Association—Pittsburgh, Pa., Monthly Meetings.
Southern Association of Stove Manufacturers—Louisville, Ky., March, 1923(?).
Stoker Manufacturers' Association—May or June, 1923.
Tile Manufacturers' Credit Association—Beaver Falls, Pa., Quarterly Meetings.

[1] Supply exhausted; can be consulted in libraries, list of which is given in Supplement No. 3 to Circular 24.

March, 1923 **The Journal of the American Ceramic Society** Vol. 6, No. 3

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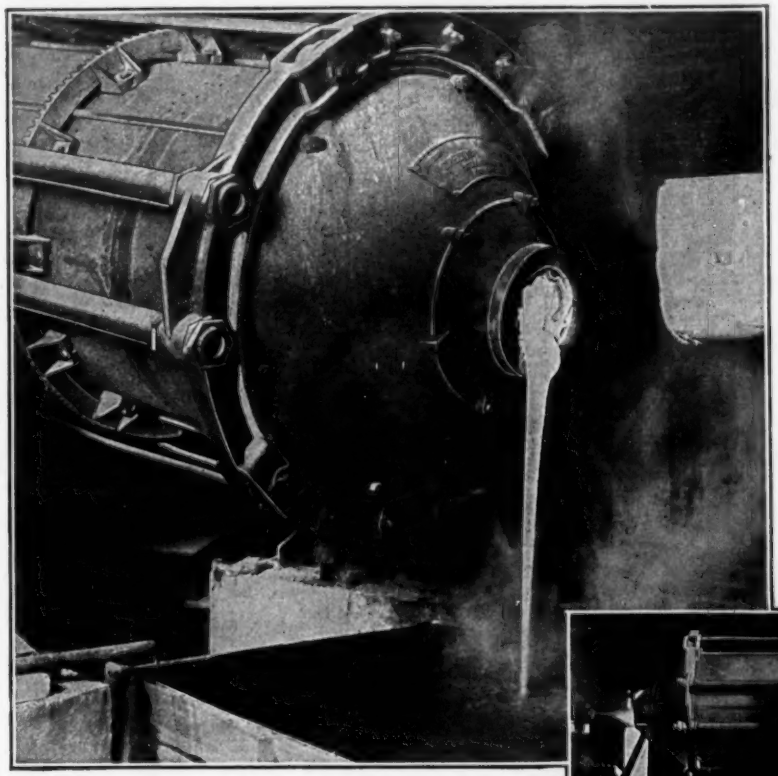

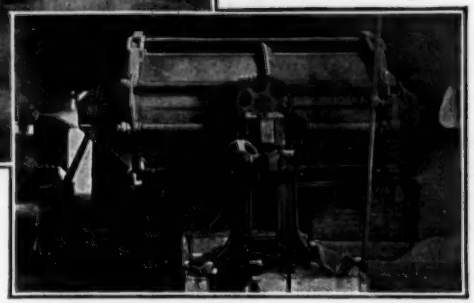

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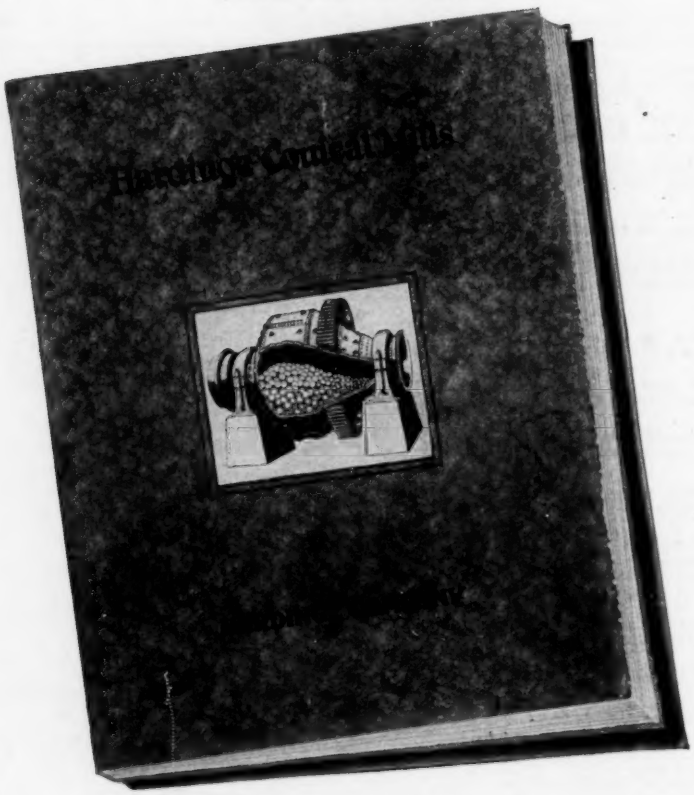

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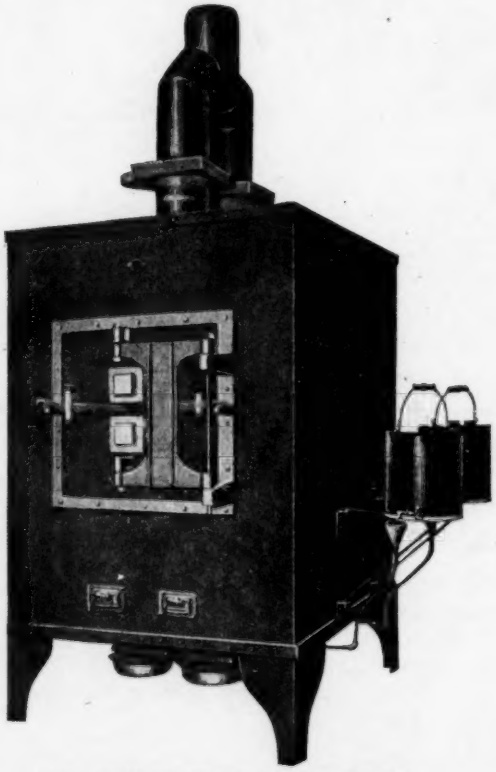

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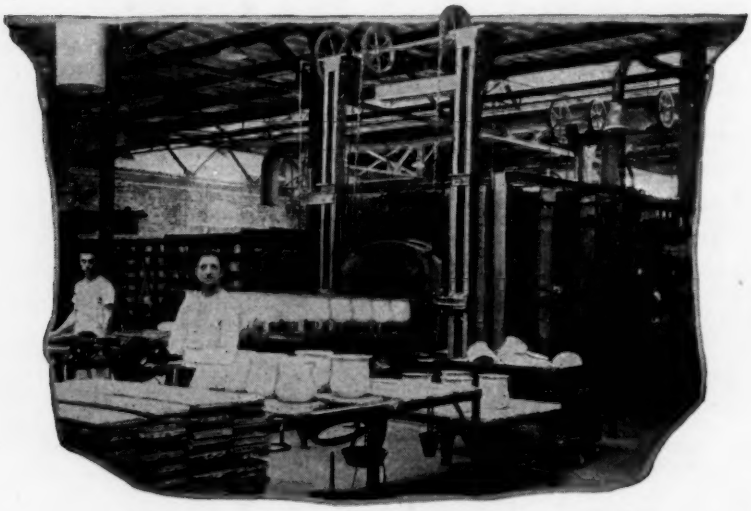

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	Page
Bowman Coal Company	20
Brown Instrument Co.	16
Chambers Brothers Co.	20
Chicago Vitreous Enamel Product Co., The	1
Drakenfeld and Co., B. F.	8
Dominion Feldspar Corporation	15
Early, J. N.	14
Edgar Brothers Co.	20
Engelhard, Charles Inc.	13
General Electric Co.	10
Golding-Keene Co.	14
Hadfield-Penfield Steel Co.	15
Hardinge Co.	6
Harshaw, Fuller and Goodwin Co.	2
Journal of the Society of Glass Technology	20
Madeira Hill & Company	21
McDanel Refractory Porcelain Co.	14
Metal & Thermit Corporation	19
Montgomery Porcelain Products Co.	15
Mueller Machine Co., Inc.	22
O'Brien and Fowler	14
Old Hickory Clay & Talc Co.	13
Paper Makers Importing Co., (Inc.)	21
Parker-Russell Mining & Mfg. Co.	12
Pennsylvania Pulverizing Co.	17
Pennsylvania Salt Mfg. Co.	22
Philadelphia Drying Machinery Co.	16
Porcelain Enamel & Mfg. Co.	Inside Back Cover
Proctor and Schwartz, Inc.	4
Roessler and Hasslacher Chemical Co.	Inside Front Cover
Seaboard Fuel Corporation	Back Cover
Surface Combustion Co.	12
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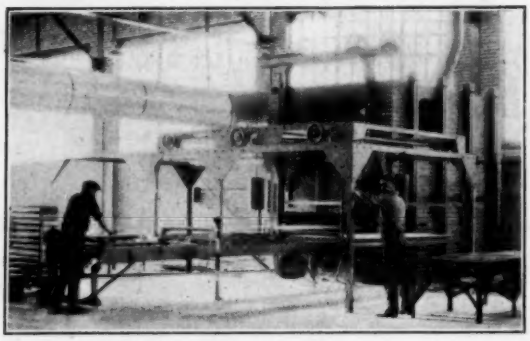

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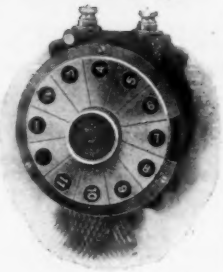

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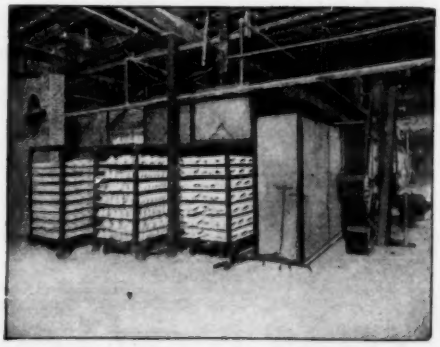

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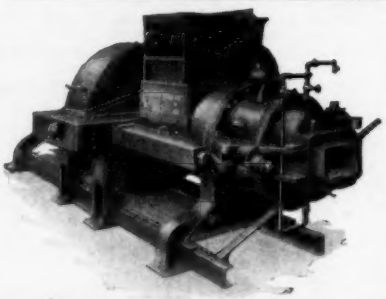

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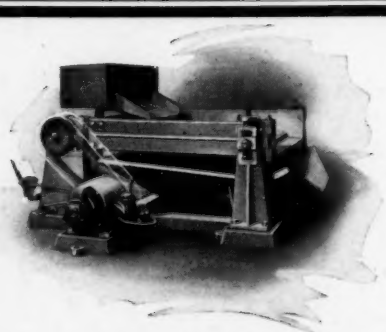

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This company has developed under its well-known PEMCO trade name, three fundamental features of operation in connection with porcelain enameling plants, covering

COMPLETE EQUIPMENT
COMPLETE LINE OF PORCELAIN ENAMELS
COMPLETE SERVICE

To each of these, we have devoted the utmost care and attention to the last detail. You can enjoy the benefit of this broad experience, with an assurance of permanent satisfaction and greatest results.

We are in position to design and equip your plant.
We are in position to furnish you with the best porcelain Enamels and such as you may require for your particular work.
We are in position to give you the best service to insure continuous and reliable production.

Put your requirements up to us.

The Porcelain Enamel & Manufacturing Co.
BALTIMORE, MD.

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